Water Power

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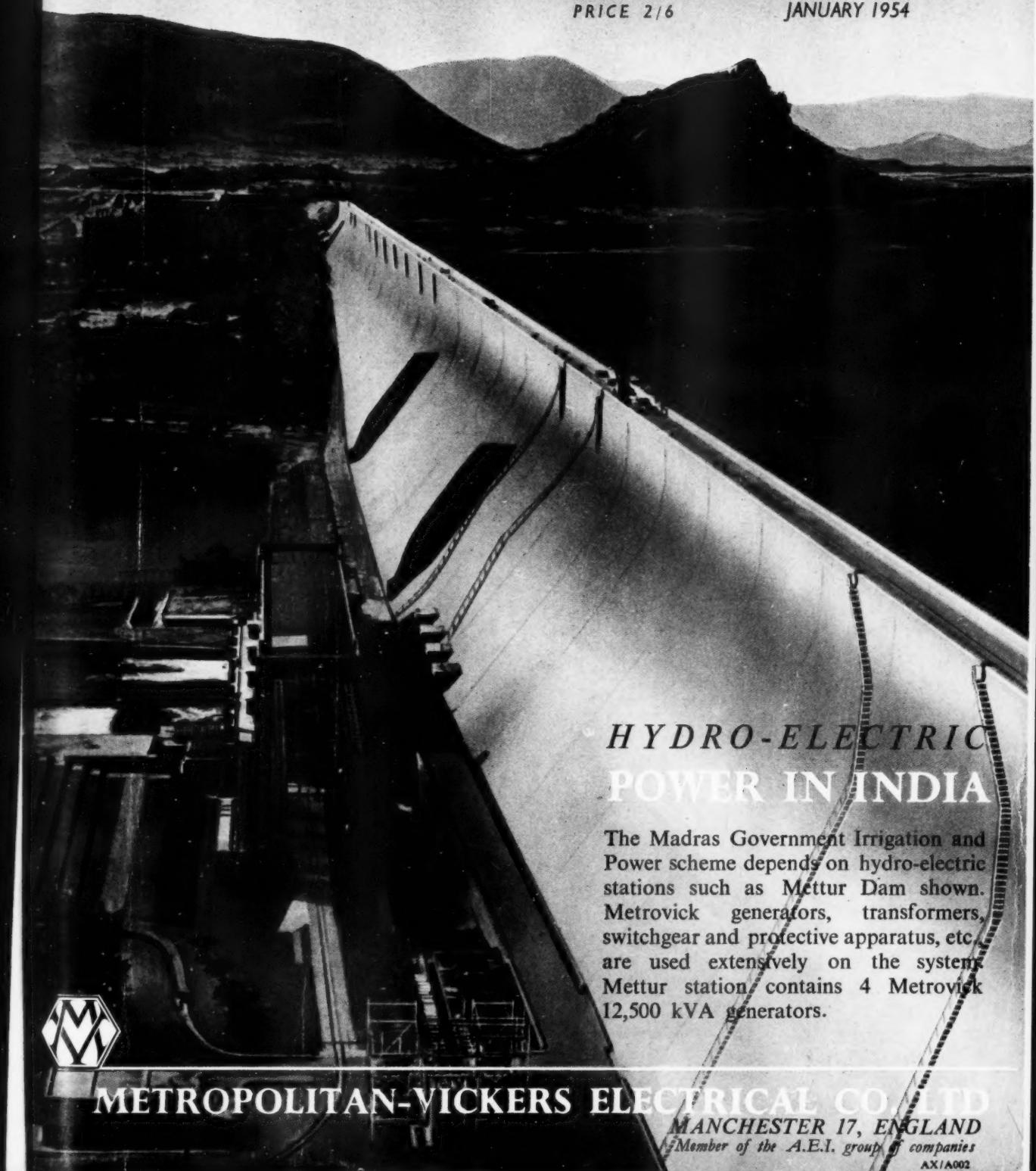
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JANUARY 1954



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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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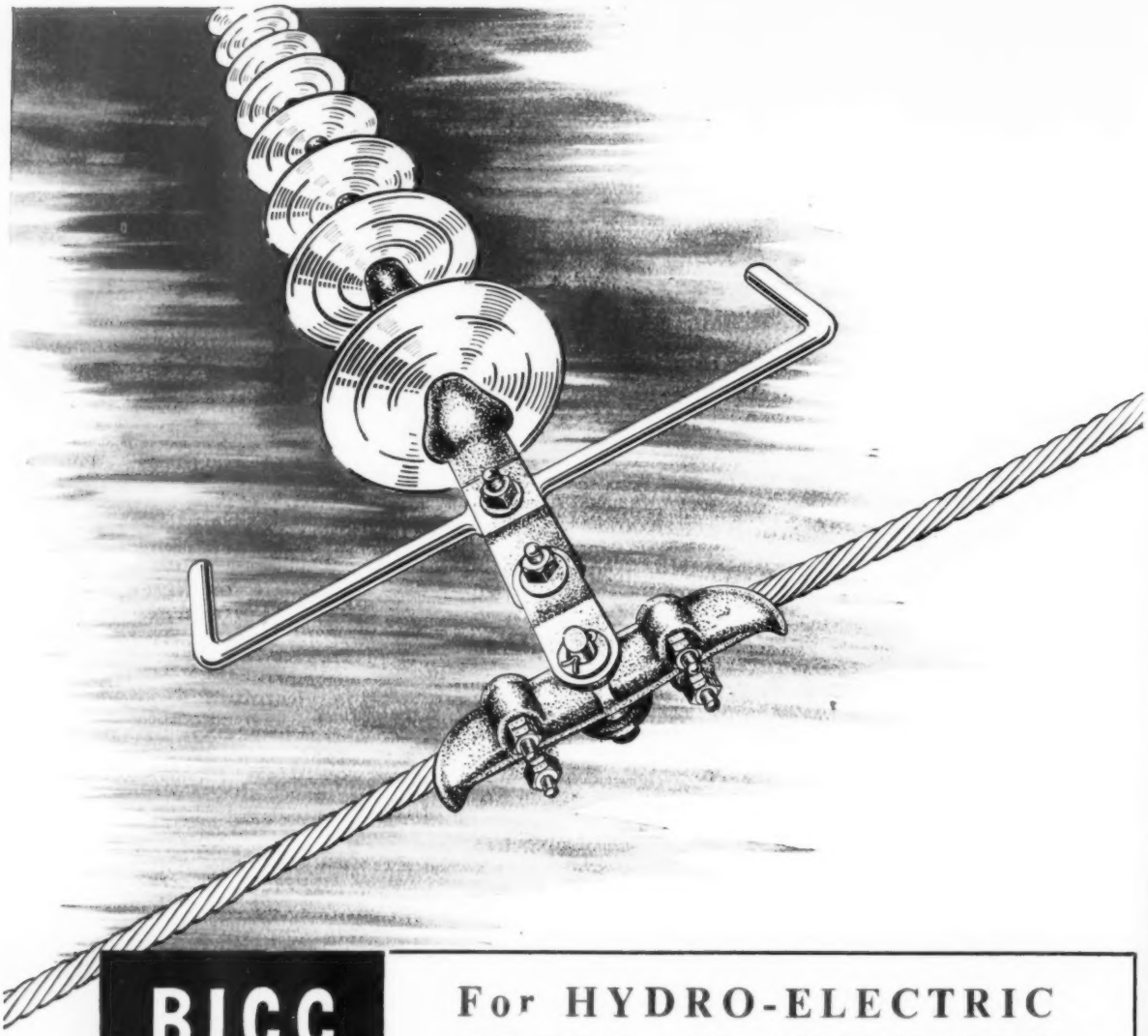

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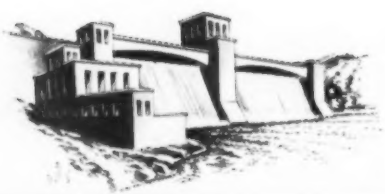

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WATER POWER

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Electrical Diversion of Fish

IN our April 1953 issue we referred to some interesting experiments which the North of Scotland Hydro-Electric Board have been conducting with the object of inducing fish to enter ladderways, on both the ascending and descending migrations. At that time, although success had been achieved with the methods which had been devised, complete data were not available, but a full account of this important work has now been published,* and we hasten to bring it to the notice of our readers.

The conception behind these experiments was to see whether it was possible to devise something less costly and troublesome than a mechanical screen to prevent migrating fish from entering the inlet tunnel on the one hand and the tailrace on the other. A further investigation was concerned with finding some method of counting the migratory fish.

Early work quickly established that sonic vibrations of varying intensity and pitch, and coloured lights, were unlikely to yield successful results but that an immediate response was obtained with pulsating electric currents. Mr. Lethlean's report deals with these responses both on a laboratory scale and with a practical sized screen erected at the Morar station of the North of Scotland Hydro-Electric Board. The items covered in the fundamental part of the research include the reactions of trout when subjected to electrical fields of various shapes and intensities, particulars of the electrode arrangements and the factors which control the characteristics of electrical fields in waters containing different amounts of impurities, the effects when fish are swimming with or against the flow of water, and the conditions necessary to attract fish to the positive electrodes. Finally, results are given of the screens actually in use and of the efficiencies obtained with them.

No difficulty appears to have been encountered in diverting fish from the tailrace tunnel across the end of which eighteen 2 in. dia. aluminium electrodes, each 14 ft. in length, were suspended vertically from a wooden framework. They were spaced 12 in. apart and reached within 3 in. of the floor of the channel. Downstream from this row of electrodes and 7 ft. distant, two 18 in. dia. electrodes were also suspended from an extension of the framework, and spaced 16 ft. apart. A system of 10 per sec. pulsations was applied to this screen by Thyratron valve units operating through metal rectifiers, the screen and outlying electrodes being divided into sections for this purpose. Observations showed that salmon sheered off from the outer electrodes when they got within 5 or 6 ft. but that sea trout did not appear to find the conditions at all uncomfortable until they were from 2 to 4 ft. away. No apparent injury was done to the fish even when they managed to penetrate deeply into the field of the closely spaced screen, and all the fish behaved in a perfectly normal way after leaving the electrified zone. An average potential of 2 volts per inch of space between the screen and the outer electrodes was maintained.

The Morar screen is considered to give 100 per cent. efficiency in a stretch of water that is recognised to be somewhat limited; for larger installations it is recommended that the outer electrodes should be placed closer together in order to spread the voltage gradients to better advantage across the zone, this having the effect of checking the smaller fish—easily the more intractable to divert—at an earlier stage.

For the descending smolts, a screen comprising two parallel rows of electrodes was suspended vertically from wire-rope catenaries and following a diagonal path from the top of the fish ladder to a point 180 ft. upstream on the opposite bank. The electrodes reached to within a foot of the floor of the reservoir and were spaced at intervals of 1 ft., the distance between the two rows being 6 ft. Those on the downstream side consist of 272 aluminium tubes, 2 in. dia., connected electrically into groups of eight with alternate groups jointed to two supply cables. A similar method of connection was adopted for the upstream electrodes but in this case the 34 groups of eight were clamped around 7 in. dia. discs spaced

* An Investigation into the Design and Performance of Electrical Fish-Screens and an Electric Fish-Counter." By N. G. Lethlean. *Transactions of the Royal Society of Edinburgh*, Vol. LXII—Part II (No. 13), 1951-53. Published by Messrs. Oliver & Boyd, Tweeddale Court, Edinburgh. Price 13s. 6d.

at 8 ft. centres—an arrangement which served the double purpose of giving large electrode areas and equal weight on the two catenary cables. The pulser unit incorporates two double-wound electro-magnetic circuits having one winding on each core connected to an a.c. supply and the other two windings to the valve grid circuits. The d.c. fluxes divide between the pole tips and opposite limbs in one half of the cores, and an iron stud, carried by a synchronous motor-driven brass disc, periodically lowers the reluctance of each gap in turn and causes voltages to be induced in the grid circuit windings.

It is concluded that this type of smolt screen showed great promise of achieving success but it was recognised that the angle chosen for the line of the screen was too acute to the axis of the dam and that the path of the screen should lie at an angle of at least 45° to the axis.

As regards fish counting, the device adopted has been found to operate successfully for a period of over twelve months and with a negligible amount of attention. The method consists virtually of an underwater electrical bridge and depends on the sequence of alterations to the electrical conditions inside a special detector tunnel (lined with "Alkathene") when a fish enters. The records are indicated remotely and the apparatus is not only adjustable to take cognisance of limiting sizes but is also able to operate in waters of widely varying chemical content. Moreover it is unaffected by the normal type of debris carried downstream with spate waters, and will totally ignore such foreign elements as branches of trees, milk bottles and even empty food cans.

French Hydro-Electricity

ACCORDING to a Board of Trade Overseas Economic Survey on France,* the Monnet planners in 1946 decided to aim at an increase in the total production of electric power with a reduction in the total consumption of coal. Hydro-electric sources were to be developed increasingly and thermal power called upon only to the extent necessary to meet the shortfall between hydro-electric production and the needs of consumption. By 1951 production of hydro-electricity by the nationalised Electricité de France had, as a result, reached a level more than double that of 1938, while production of thermal power had risen by just over 60 per cent. In 1952 total production of hydro-electricity in France rose by a further 6 per cent. to 22·5 milliard kWh (17·5 milliard kWh contributed by the Electricité de France). Consumption has developed apace and for 1952 amounted to 40·8 milliard kWh, that is, 114 per cent. above the level of 1945 and 93 per cent. above the level of 1938.

In the mountain ranges of the Alps, the Juras, the Massif Central and the Pyrénées and in the rivers Rhine and Rhône in particular, France is naturally endowed with considerable water-power potential. It is in these areas that the greatest extensions to the hydro-electric system have taken place. Reservoirs have been an important feature of post-war development. Chief among the construction projects was the dam at Génissiat on the Rhône, 33 miles from the Swiss frontier, which was conceived to supply power to the second largest hydro-electric installation in Europe, and which went into service gradually from 1947 onwards. In 1952 the great Donzère-Mondragon development began operation, again to utilise the water power of the Rhône and at the same time to improve navigation in a difficult stretch of the river and to provide a new water level for irrigation. Another great work is at Ottmarsheim on the Rhine. In 1952 the Alpes-Jura-Rhine group of hydro-electric power stations contributed 57 per cent. of total hydro-electricity production, the Massif Central group 24 per cent. and the Pyrénées group 19 per cent. Sixteen new hydro-electric installations were brought into service in 1952.

* "France: Economic and Commercial Conditions in France." By E. W. Meiklereid. H.M. Stationery Office, price 5s. net.

Swedish Pumped Storage Plant

CONSTRUCTION work has begun on a new pumped-storage cum generating plant which has been projected by Uddeholms Aktiebolag, Hagfors, Sweden. The power station will be of the underground type and will house two turbine-generator-pump units. The pumps, which have been ordered from the Riva Company of Milan, will be of the double-inlet horizontal-impeller type and designed to operate at heads ranging between 200 and 174 m. At the mean head of 187·5 m. each pump will be capable of discharging 8,500 cu. m. per sec., absorbing 24,200 h.p. The speed will be 500 r.p.m.

The plant will be situated some 200 km. north of Karlstad and will constitute one of the largest pumped-storage plants in Sweden. It will be used chiefly during the springtime to raise water to Lake Letten, the storage capacity of which has been substantially increased by the construction of two earth-fill dams.

A New Swiss Hydro-Electric Venture

A NEW hydro-power generating concern has been founded in Sitten, Switzerland, under the style of "Electricité de la Lienne S.A." for the purpose of utilising the power resources of the Lienne catchment area and of the neighbouring areas, and distributing energy to the Bernischem Kraftwerken A.G., the Lonza concern, the city of Basle and its canton, the Sitten Community, and the Energie Ouest-Suisse (EOS). The initial company capital, Fr. 15 million, i.e. about £1,230,000, of which 20 per cent. has been paid in, has been subscribed by the concerns and corporations mentioned above, of which the first four are to absorb each 25 per cent. of the energy produced.

First 66 kV Cable in Africa

TWO years after supplying and installing 33 kV cables between Salt River power station and Cape Town and two new substations at Oakdale and Elsies River, British Insulated Cables (South Africa) Ltd., an associated company of the B.I.C.C. Group, has been awarded an extension to the contract, involving the use of the first 66 kV cables, which will also be the first of the impregnated pressure type to be used in the Continent, and will carry a further 43 MVA per feeder between Salt River and Oakdale. Two new 66 kV cables will be laid between Salt River power station and Oakdale substation, a distance of approximately 11 miles, and a further 33 kV cable between

the power station and Elsies River, approximately seven miles away. The cable route to Bellville follows part of the new national road between Cape Town and Johannesburg.

Tiszalok Irrigation Project Nearly Ready

BUILDING of the Tiszalök hydro-electric dam in north-east Hungary is so near completion that builders have given a target date for the opening of the first section of the irrigation scheme for the Hortobágy plain. On April 4, it is announced, the first 28 miles of the Eastern canal, which will eventually link the Tisza and the Berettyó rivers, will be flooded from the dam. At the same time 22 miles of irrigation branches from the main canal will come into operation. This will make possible the cultivation next spring of 35,000 acres of hitherto unproductive soil. Most of it will be put down to rice.

Ontario Hydro Power

AN unusually low flow in the Ottawa River has reduced the output of the power plants related to this system to the extent of over 20 million kWh and the more expensively run thermal plants at Toronto and Windsor have had to work to full capacity to make good the shortage. In commenting on this situation, Mr. R. H. Saunders, Chairman of the Hydro-Electric Power Commission of the Province, stated that it gave point to the necessity for pressing forward with the St. Lawrence Waterway project, although the Sir Adam Beck No. 2 plant would be able to afford some relief by the winter of 1954. In the meantime, arrangements had been made to purchase extra power from the Beauharnois station of the Quebec Hydro-Electric Commission and from the Detroit Edison Company. Some 44 per cent. of the peak load, Mr. Saunders added, depended on water power and there was an urgent need for additional generating capacity.

New Zealand Financial Report

NEW ZEALAND State Hydro-Electric Department's report shows that during the year ended on March 31 last, capital expenditure reached £13½ million. Of this, £7¼ million were spent on new hydro-electric stations. Transmission lines and substations accounted for another £4 million. The cost of surveying and investigating geothermal projects was £300,000. The department's revenue for the year was £4¼ million, and the operating costs, at £3 million, left a gross profit of more than £1½ million. This was more than accounted for by capital charges—interest and depreciation—and the overall loss for the year amounted to £600,000. The capital invested in hydro-electric undertakings is now nearly £85½ million.

Quebec Developments

A CONTRACT by which the Quebec Hydro-Electric Commission will sell The Shawinigan Water and Power Company 400,000 h.p. of electrical energy from the Commission's new development on the Bersimis river has just been announced, and is believed to be the largest single power contract ever made in Canada and one of the largest anywhere. Mr. Fuller, President of the Shawinigan Company referred to the agreement as an historic event which provided concrete evidence of the government's desire to give private enterprise the opportunity to carry on and foster industrial development in the Province.

The Bersimis hydro-electric development, now under construction on the Bersimis river, about 90 miles above its confluence with the St. Lawrence, will have an ultimate capacity of nearly 2,000,000 h.p. The first generators are expected to be in operation towards the end of 1956.

The Shawinigan Company will begin to take delivery of 80,000 h.p. on December 1, 1956, and an additional 80,000 h.p. progressively in each of the next four year, so that by the beginning of 1961 the full 400,000 h.p. will have been accepted.

Italian Impulse Turbines of 150,000 h.p.

THE Societa Elettrica Bresciana has begun construction work on the new Cimego hydro-electric power station, in the Italian Alps, which, it is believed, will house the most powerful horizontal impulse units yet built. These will comprise two twin-runner Pelton-type Riva turbines each capable of developing 150,000 h.p. under a head of 727 m. (2,363 ft.), at a speed of 300 r.p.m. Each of the twin runners will weigh about 40 tons, have a diameter of 4.500 mm. (14 ft. 8 in.), and will be operated by a single straight-flow nozzle as designed and patented by the Costruzioni Meccaniche Riva of Milan and described on page 155 of our April 1952 issue. Between each pair of overhung runners a three-phase alternator will be mounted having a rated capacity of 110,000 kVA and operating at 13,800 V ± 10 per cent. These machines will be manufactured by Ercole Marelli & Co. S.p.A. of Milan, and each will have a weight of 650 tons and a flywheel effect of 4,300,000 kg.m².

The Cimego project is being developed by the Direzione Costruzioni Impianti Idroelettrici, a subsidiary of the Edison Company of Milan, which is responsible for planning and supervising the construction of works of this kind.

Lillooet Contracts

CONTRACTS amounting to $8½ million have been awarded by The British Columbia Electric Company for a hydro-electric plant on the west bank of the Fraser River a mile below Lillooet. The plant will use the tailwaters of the Bridge River station and will comprise two low-level dams, a 12,000 ft. concrete-lined canal, and a 42 MW power station.

Shire Valley Project, Nyasaland

A SURVEY is now being made of the Shire valley with a view to regulating the flow of the river by the construction of a storage dam and developing a substantial block of power from the impounded waters. Besides providing electricity at very favourable rates the scheme would also enable large tracts of the lower portion of the Shire valley to be irrigated, thus enabling useful crops to be produced from land which is at present entirely derelict. This double benefit, in the words of Sir Geoffrey Colby, the Governor, would revolutionise the economy of Nyasaland and enable the future of the territory to be regarded with the utmost confidence.

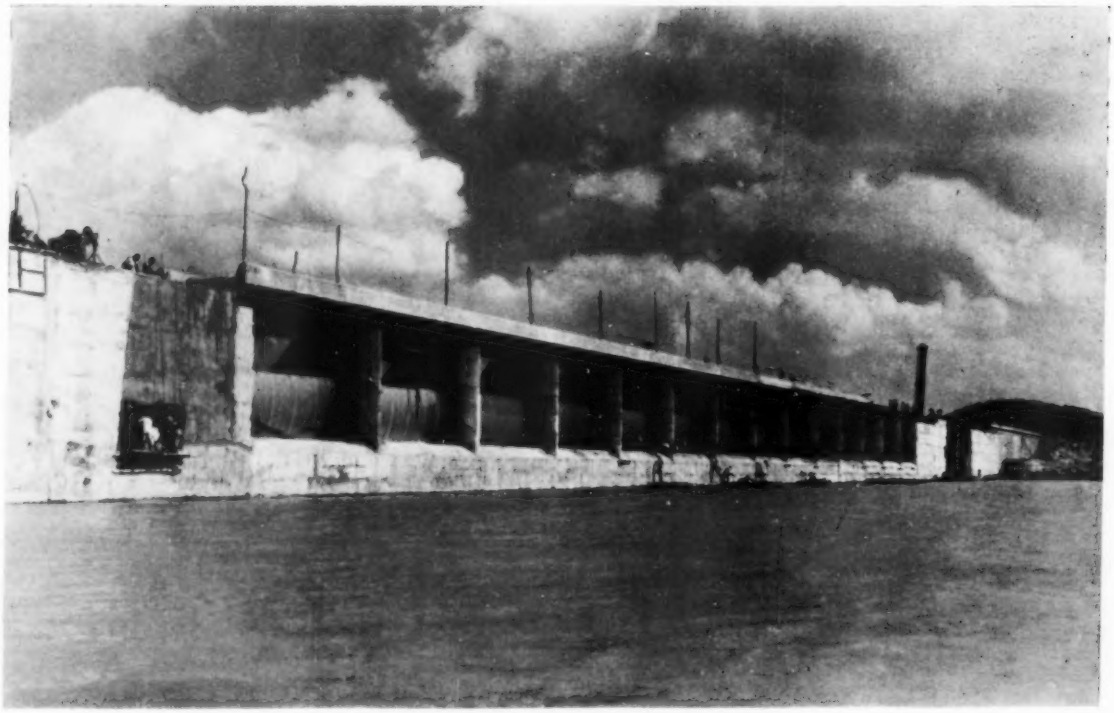

Fig. 5. View of Tilaiya dam from upstream

Damodar Valley Project

In this instalment the Tilaiya and Konar dams and the power plant at Tilaiya are described, the projected underground station at Konar is discussed, and brief mention is made of the thermal station at Bokaro

PART TWO

OF the seven dams proposed in the valley development scheme, three are located on the Barakar river, a tributary of the Damodar, and the Tilaiya dam, sited at the uppermost reach about 130 miles above the confluence of the two rivers, is the first to be completed so far. It is also the first dam to be completed anywhere in India since the end of the war, and has the distinction to be the first concrete dam to be built in the country. It is not a big dam as dams go; in fact, it is the smallest dam, both in height and volume, of the D.V.C. It is a concrete gravity structure, 94 ft. high above the deepest river bed and 1,147 ft. long at the road level. At the dam site, the river bed is about 300 ft. wide, the right bank rising 100 ft. in 950 ft. and then the next 50 ft. to the top of the ridge in about 750 ft. The left bank is somewhat steeper, with a slope of 1 in 5·5 for the first 100 ft. and then about 1 in 16 to the crest. A suggestion in favour of an earth dam was rejected in view of the availability of good-quality rock for concrete aggregate at the dam site. A 400 ft. wide belt consisting of quartzites dipping vertically runs across the ridge at the site. Upstream of the quartzite belt occur mica-schists interspersed with quartz veins, while downstream of the belt outcrops of finely decomposed fine-grained granite-gneiss are found. Much of the ridge is covered with quartzite debris and weathered surface rock of about 5 to 10 ft. thickness. The river bed is covered with a layer of river sand varying in depths from 5 to 40 ft.

The spillway is 510 ft. long including the piers, the spillway crest being 22 ft. below the road level. The right and left abutments are 407 and 230 ft. long respectively, the power house being located on the left bank immediately below the abutment (Fig. 1). The design figure for maximum discharge is 132,000 cusecs over the spillway and through the under-sluices, the spillway discharge being controlled by fourteen tainter gates, each 10 ft. high by 30 ft. long, and the two under-sluices 30 in. in diameter being located in the spillway under each of the last two piers near the left abutment. The total volume

of the water impounded at the top-of-gate level is 320,000 acre feet, of which 260,000 acre feet (from level 1,222 to 1,192) is the live storage. Uncontrolled flood storage (from level 1,230 to 1,222) is 130,000 acre feet. The average tailwater level is 1,135, thus giving a maximum head of 95 ft. and a minimum of 57 ft. for the turbines.

A cross-section of the dam and the power house is shown in Fig. 7. The power house is designed for an initial installed capacity of two 2,000 kW generators with provision for a third set at a later date. This is expected to meet the demand for power in the adjoining areas in the first five years. About 22 million kWh are expected to be available per year, of which a little over 9 million will be secondary power available only during the monsoon after the station is linked with the D.V.C. grid. The two generating units, both of which have now been commissioned, complete with all auxiliaries, switchgear, transformers and outdoor substation are of Japanese manufacture, the first of their kind to be used in India. They were supplied by Mitsubishi Electric Manufacturing Company and Central Japan Heavy Industries Limited for approximately £90,000, about a third of the price quoted by European and American manufacturers.

TABLE II: CHARACTERISTICS OF THE TILAIYA TURBINES AND GENERATORS

Turbine	
Rated output	2,800 h.p.
Maximum head	100 ft.
Rated head	64 ft.
Minimum head	49 ft.
Efficiency at full load and rated head	88·5 per cent.
Speed	250 r.p.m.
Discharge for the rated output and head	438 cusecs
Diameter of penstock	7·5 ft.
Runaway speed under rated head ...	487 r.p.m.
No. of runner vanes	15
No. of guide vanes	20
Generator	
Rated normal output	2,500 kVA
Output on overload for two hours	3,000 kVA
Power factor	80 per cent.
Terminal voltage	11,000 V
Maximum efficiency at 100 per cent. p.f.	95 per cent.
Weight with exciter	58 tons

The turbines and the auxiliaries are designed for remote-controlled operation; the circuit - breakers are solenoid operated and the entire plant is capable of central control from the control room, annunciation being provided by means of lights and instruments for indicating the operation conditions at every stage. The control is provided by means of an oil-pressure system and the control apparatus consists chiefly of solenoid-operated oil valves and oil pressure relays closing or opening electrical circuits. The main characteristics of the power plant are given in Table II.

One interesting feature of the erection was the shrinking of the rotor on to the main shaft. The rotor was induction heated by winding 22 turns of 0·15 sq. in. copper conductor; 220 V 50 cycles, single-phase current was applied to this winding and 260 A were taken from the mains. The required temperature rise of 100°C. was reached in about 14 hours.

There were no consulting engineers on the job and the work was done departmentally by direct labour. The work was actually commenced in January 1950, but the placing of concrete was not begun until a year later. At first, concreting was done by the traditional Indian method of a human chain of head baskets, a method ill-adapted for large-scale construction projects like dams but inevitable in the existing circumstances. By December 1951 the construction plant had been fully mechanised, the principal

Fig. 6. Tilaiya dam and power house from left bank

Fig. 7. Section through Tilaiya power house

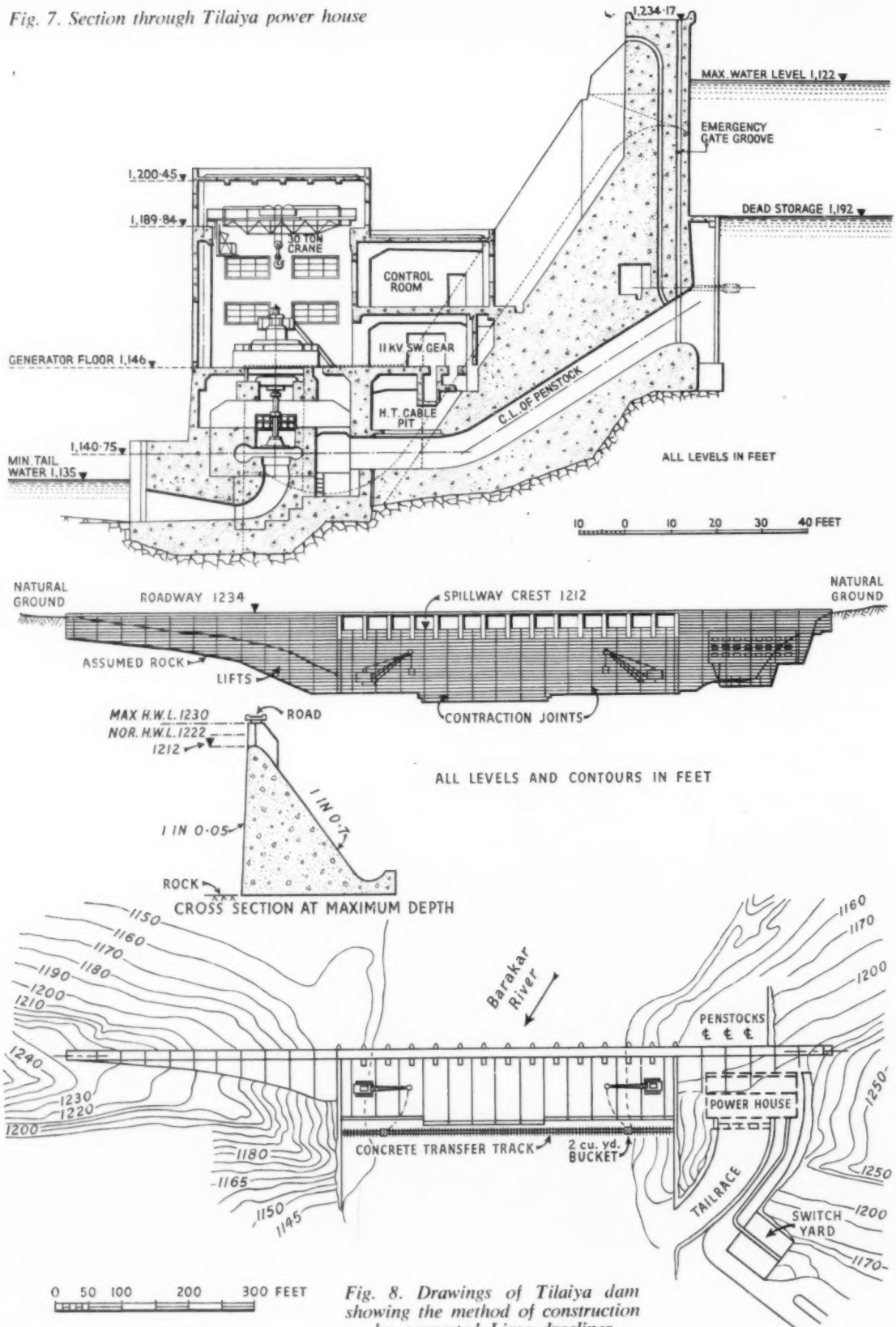

Fig. 8. Drawings of Tilaiya dam showing the method of construction by converted Lima draglines

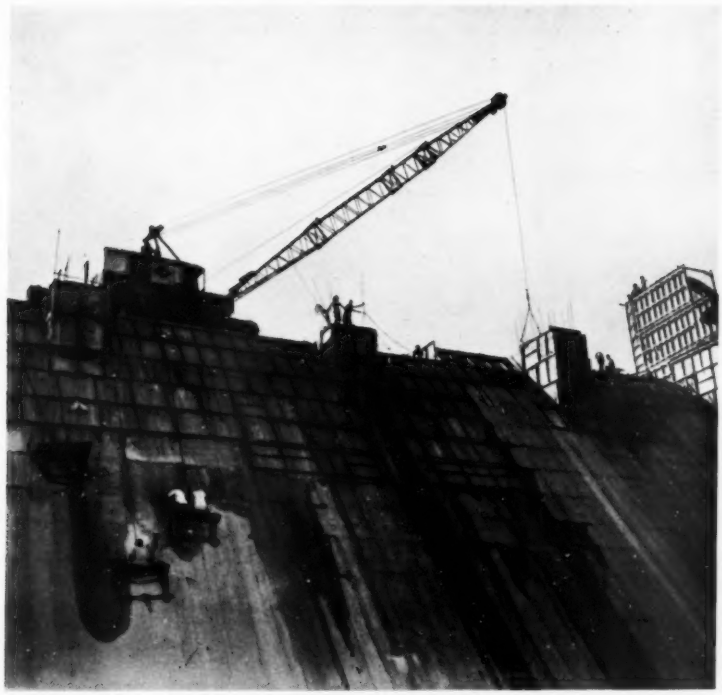

Fig. 9. One of the converted Lima draglines at work on the dam

equipment consisting of two Lima 2½ cu. yard draglines, one Northwest 1½ yard shovel dragline, two Blaw-Knox concrete batching plants with 2 yard capacity tilting mixers, one Baxter 50 tons per hour stone crusher, one Cedarapids 50 tons per hour primary and secondary stone crusher, six Blaw-Knox bottom-dump concrete buckets of 2 yard capacity, 13 air-compressors from 300 to 500 cu. ft. capacity, six diesel-driven locomotives for hauling the concrete buckets, and six Chicago pneumatic concrete vibrators.

An unusual feature of construction procedure is illustrated by the accompanying sketch (Fig. 8) and photographs. In order to adapt the equipment at hand to suit a reasonable construction schedule, two 2½-yard capacity Lima draglines were converted into concrete-placing cranes. These handled the bottom-dump buckets and placed concrete in 4 ft. layers. At the end of the given cycle across the dam the draglines were walked up to a 4 ft. higher elevation on to an adjacent block by means of a prepared wooden ramp where they continued concreting on the next lift. At the end of the final concreting, the two cranes were walked from the dam on to either embankment. The chief engineer of the D.V.C. has described this method of "concreting by pulling up the cranes by their bootstraps."

The dam was completed early in 1953 along with the power station. Final estimates are not yet available but the whole works are estimated to have cost about £2 million.

Bokaro Thermal Power Station

An important plant is the new Bokaro thermal station (Fig. 17) with an installed capacity of 150,000 kW initially and 200,000 kW eventually with the addition of a fourth 50 MW set. As explained earlier, the thermal station is necessary for firming up the hydro

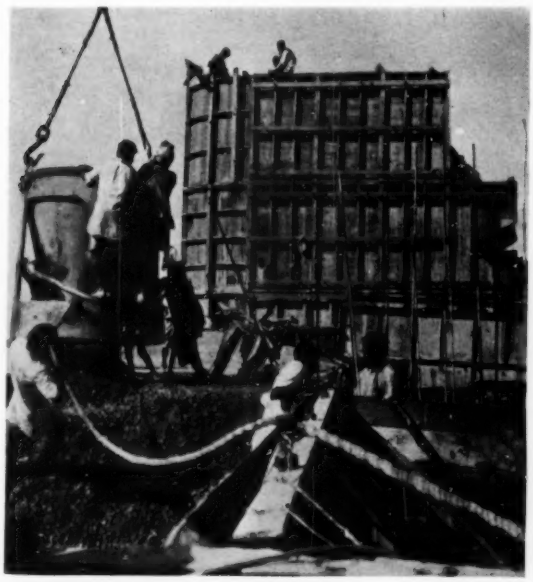

Fig. 10. Concreting a spillway pier

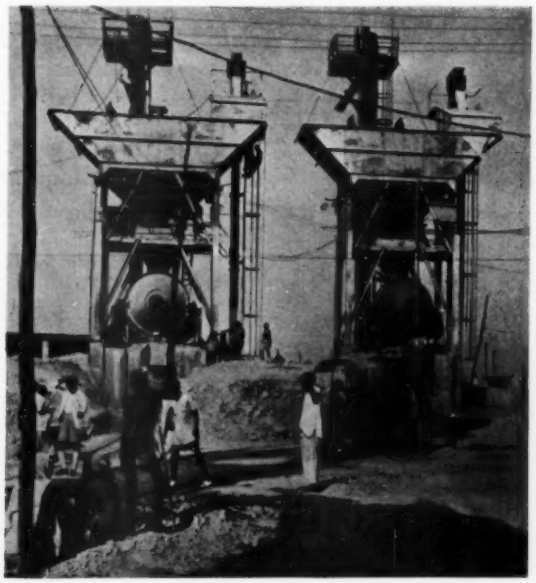

Fig. 11. Tilaiya dam batching plant

Fig. 12. Cross section through concrete spillway section of Konar dam

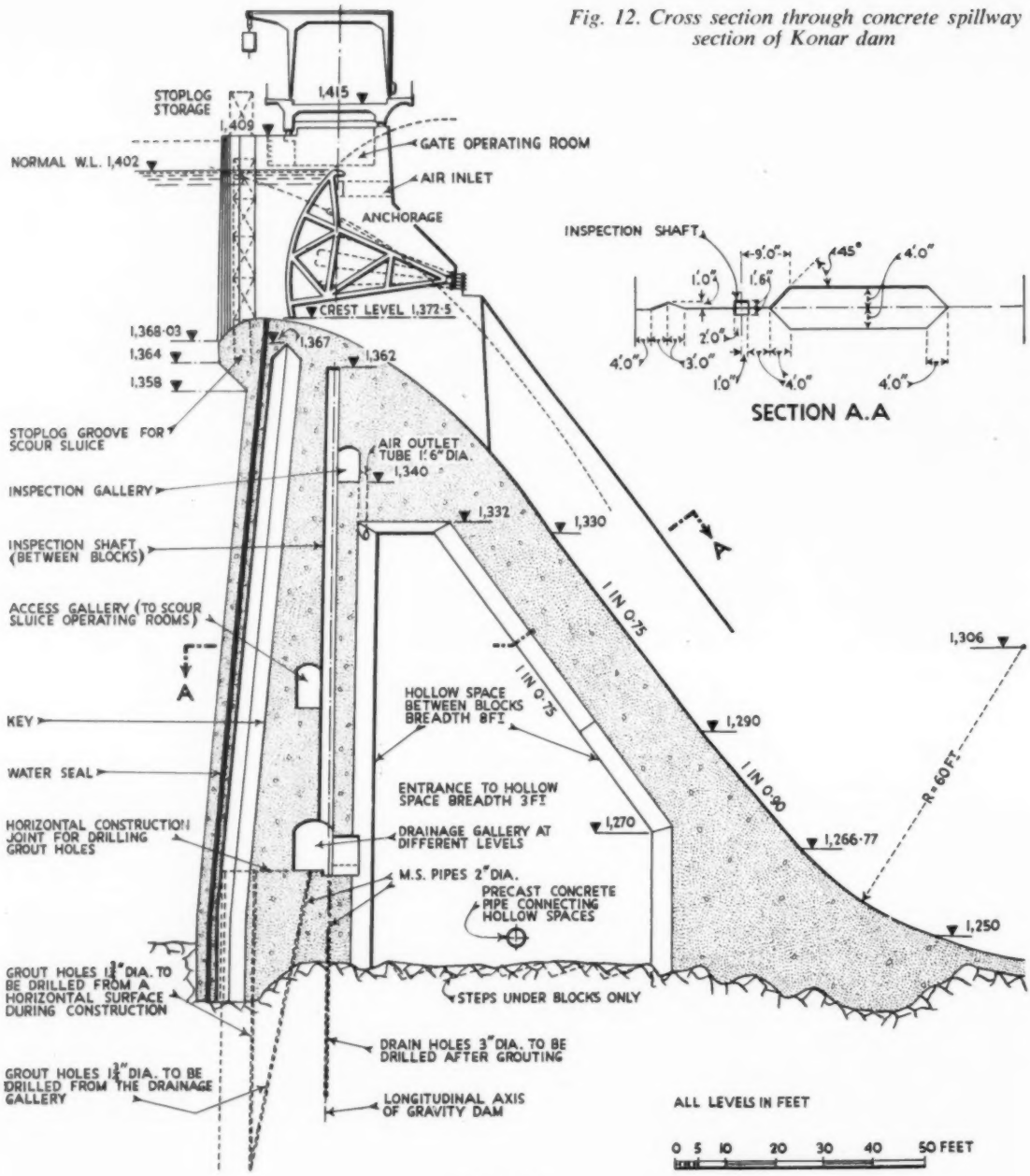

Fig. 13. Section through Konar dam earth embankment

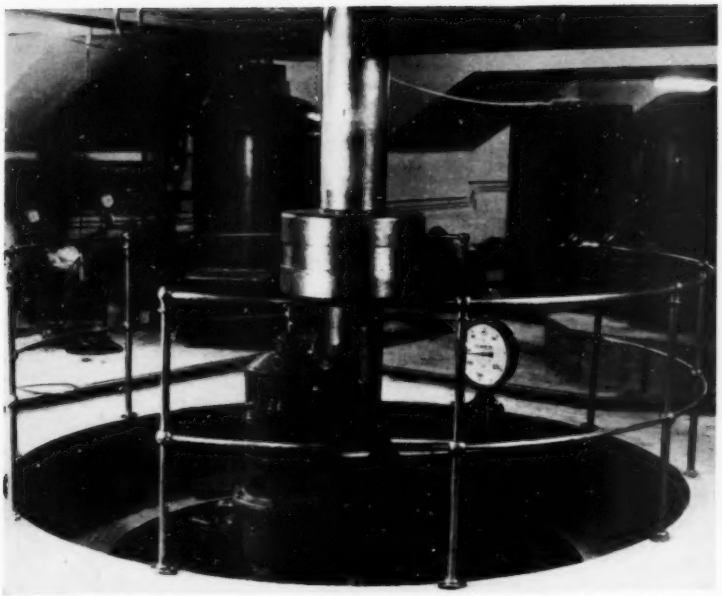

Fig. 14. One of the Tilaiya 2,000 kW sets at shaft level

power during the dry season and also to generate sufficient power to cater for the existing as well as future demand which cannot possibly be met from the hydro stations. The station, reputed to be the most modern in Asia and probably the biggest so far, is fully automatic and will utilise low-grade coal with 26 per cent. ash content, thus helping in the conservation of badly needed high-grade coal for the country's iron and steel industry. The station is designed on the unit system, two boilers of 300,000 lb. per hour capacity at 895 lb. per sq. in. and 910°F. being used for supplying steam to each 50 MW turbo-generator. The working pressures and temperatures are a record for this part of the world and so is the fact that the generators are hydrogen-cooled. The station was designed and supervised by the Kuljean Corporation of Philadelphia and was constructed by the International General Electric Company of New York, who supplied most of the electrical equipment. It has so far cost about nine million pounds including a barrage for storing cooling water from the Konar river. Two sets have already been commissioned and the third is expected to be ready shortly.

Konar Dam

The Konar dam, on the river Konar about 15 miles upstream of its confluence with the Damodar river, will impound 260,000 acre feet of water at level 1,402, top of gates, about 156 ft. above the river bed. It includes a concrete gravity-type structure about 900 ft. long comprising the spillway (Fig. 12) with earth

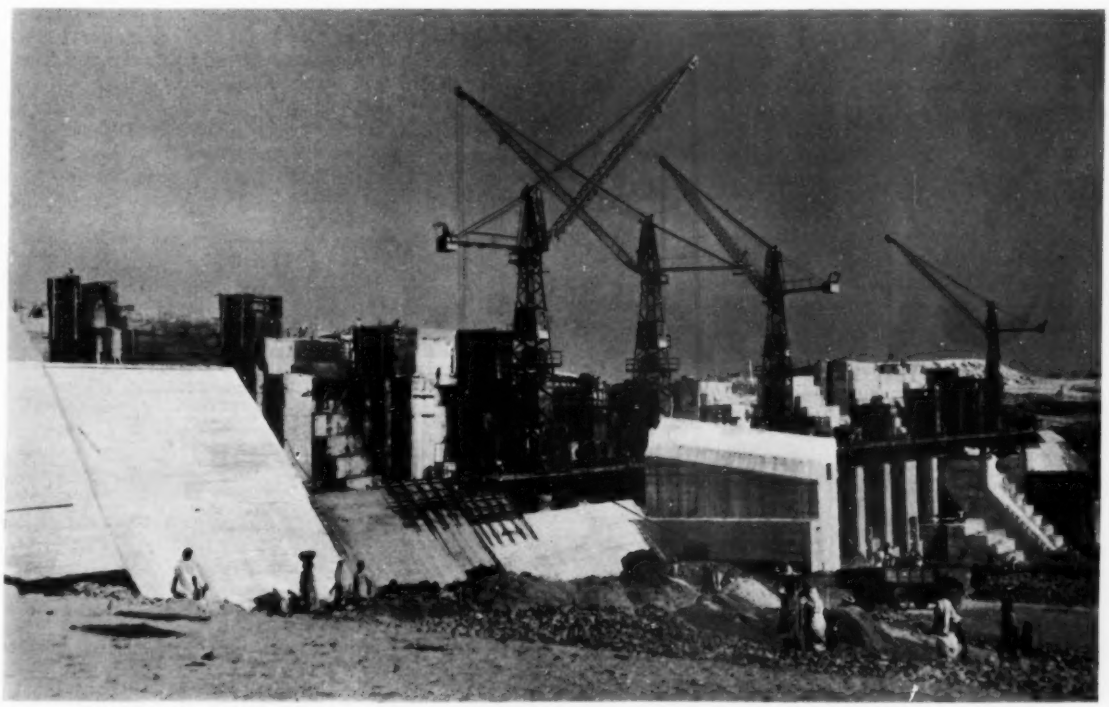

Fig. 15. View from right bank of Konar concrete dam under construction

Fig. 16. Konar earth embankment under construction

embankments on either side (Fig. 13), the left one about 4,000 ft. long and the right one 5,800 ft. long. There will also be a saddle dyke 2,200 ft. long with a maximum height of 22 ft. The spillway is designed for a maximum flood of 240,000 cusecs controlled by nine tainter gates, each 32 ft. high and 34 ft. long. In addition, there are two under-sluices each 7½ ft. in diameter located in the spillway.

The Konar dam has a threefold purpose: irrigation, power, and supply of cooling water to the Bokaro thermal station at a steady rate of 400 cusecs when the station is in full operation. This station, which is on the banks of the Konar river about 12 miles below the dam site, has been provided with a 20 ft. high weir sufficient to impound a storage of 60 million cu. ft. directly controlled by water releases from the Konar dam. The final scheme for power generation is in the process of development, and out of five or six schemes under consideration at one time, it appears that an underground hydro power station immediately below the dam will be selected as the most economic from power point of view, although not so feasible from the point of view of construction. The scheme will consist of an installation of two 20,000 kW units working under a maximum head of 600 ft. at full storage level and about 550 at the maximum drawdown. The tailrace tunnel will be seven and a half miles long. It is expected that the plant will have an average annual output of about 191,000,000 kWh, of which nearly 150,000,000 kWh will be primary energy and the rest secondary, available during the monsoon. The underground station will be the first in Asia, although it is early to say whether the difficulties involved in a job of such a magnitude and character can be overcome in time to make the power available by 1956, the year of completion of the first stage of the Damodar project.

Neither Tilaiya nor Konar reservoirs have been

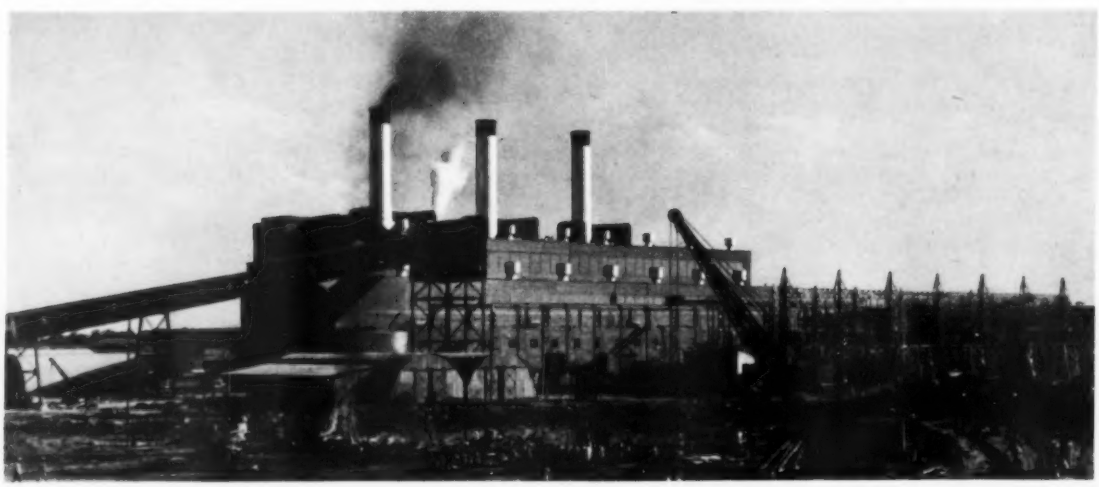

Fig. 17. Bokaro thermal power station, built to supplement D.V.C. hydro power

TABLE III: STATISTICAL DATA ON TILAIYA AND KONAR PROJECTS

	Tilaiya Dam	*Konar Dam*
Catchment area	380 sq. miles	385 sq. miles
Flow:		
Maximum	48,439 cusecs	20,645 cusecs
Minimum	nil	nil
Average	560 cusecs	560 cusecs
Storage:		
Total	320,000 acre ft.	260,000 acre ft.
Live	260,000 acre ft.	211,000 acre ft.
Dam:		
Height	99 ft.	160 ft.
Length	1,147 ft.	12,959 ft.(1)
Spillway capacity	131,500 cusecs	240,000 cusecs
Benefits:		
Power: installed capacity	4,000 kW (present) 6,000 kW (future)	40,000 kW
Head: maximum	95 ft.	608 ft.
minimum	57 ft.	547 ft.
average	87 ft	602 ft.
Total units per year	22,770,000 kWh	191,000,000 kWh
Irrigation	99,000 acres	104,000 acres(2)

(1) This consists of 910 ft. of gravity-type dam
9,800 ft. of earth embankment
2,249 ft. of saddle dykes.

(2) In addition to these benefits, Konar reservoir supplies Bokaro power station with a continuous cooling water supply of 400 cusecs.

provided with any flood reserve as this has been concentrated at the last two dams, viz., Maithon and Panchet Hill. This is expected to eliminate the conflict between power and flood control in the operation of the upstream reservoirs. According to the consultants, the flood storage, if scattered over seven dams in the valley, would lose much of its effectiveness. Generally the storms in the valley are local and so the flood-control provisions in the dams of the upper reaches may be partially or wholly ineffective. Both Tilaiya and Konar dams, therefore, will store water for irrigation and power only, the latter, however, acting, in addition, as a controlling headworks for the cooling-water supply for Bokaro.

Construction work on the earth dams was begun in October 1950, together with the stripping of the main dam site and borrow pits. The concreting of the central spillway section was begun in April 1951. Dewatering presented no serious problem as the site is fairly good, the foundation rocks consisting mainly of pegmatite and gneisses. The entire construction work has been let out to Hind Construction Company and Patel Engineering Co. Ltd., of Bombay, and although there was, at first, some difficulty regarding heavy construction machinery such as cranes, shovels and draglines, this has now been overcome and the work is in an advanced stage. Approximately 50 per cent. of the concrete dam and just over 50 per cent. of the earth dam have been completed. Gruner Brothers of Basle, Switzerland, designed the dam and are supervising the construction.

Table III gives a brief statistical summary of the Tilaiya and Konar projects.

(To be continued)

Kitimat Tunnel Holed

The 10 mile tunnel from Tahtsa lake to the underground power house at Kemano has now been completed and has involved the excavation of about 2 million tons of rock. Kenney dam, which forms the main barrier to divert the flow of the water from an easterly to a westerly direction and which is the chief component in forming a reservoir capacity of 20 million acre feet, was finished some months ago, and the 43 mile transmission line between Kemano and the smelter at Kitimat is now approaching completion. The two Ferranti transformers which will be placed at the ends of this line have now arrived in British Columbia and will be installed within the next month or so. It is hoped that aluminium production will begin in the late spring. It will be recalled that this gigantic enterprise has been initiated by The Aluminium Company of Canada Limited.

A Kitimat Film

The International Harvester Company recently had on view in London a magnificent colour film, entitled "Men with a Thousand Hands," of the work in progress on Alcan's huge Nechako-Kemano-Kitimat project. It is an impressive film, not only for the grandeur of the scenery in which it is set but for the way in which it portrays the natural difficulties that are having to be surmounted in constructing this great undertaking. Some of the construction areas would have been virtually inaccessible before the advent of helicopters, which are shown fulfilling a vital role, and the rough conditions in which the large fleet of heavy International Harvester machines is used on all phases of the civil-engineering work is ably demonstrated.

The film takes us to each of the main construction sites in turn—the Kenney dam, the Kemano tunnel and underground machine hall, the transmission line which will traverse the snow-covered Kildala pass at 5,300 ft., and the Kitimat smelter plant and town site—and we are left with admiration for both the men and the machines engaged on the largest privately constructed hydro-electric development of all time.

Enfield Review. Enfield Cables Limited have sent a copy of the first number of the "Enfield Review," which is designed to bring before consumers some of the more specialised aspects of electric cable manufacture and its applications to different types of undertakings. In this issue the cabling of the B.E.A.'s new generating stations at Chadderton and Doncaster is described, and there is an interesting account of the wiring of the Coronation decorations for the Mall. It is intended that the new review will be issued four times a year to correspond with the seasons.

New President of British Standards Institution. At the Annual General Meeting of the British Standards Institution, Sir Roger Duncalfe was elected President to succeed Viscount Waverley, P.C., G.C.B., G.C.S.I., G.C.I.E., F.R.S. Sir Roger's appointment was proposed by Lord Waverley, whose three-year term of office had ended in accordance with the B.S.I. constitution. Sir Roger Duncalfe is a leader of Britain's chemical industry, and has been closely identified with standards work and the B.S.I. for more than 20 years.

Present Trends in Surge-Tank Design

We publish a summary of an important paper given in November by Dr. C. Jaeger before the Institution of Mechanical Engineers.

SURGE-TANK design has progressed a long way since the early days when a surge tank was regarded merely as a reservoir to enable successive turbines to pick up load, and in his recent paper before the Institution of Mechanical Engineers, Dr. Jaeger performed a valuable service in crystallising modern thought on surge-tank design and in contributing some of his own ideas and experience. Present-day electrical networks impose loading conditions far more onerous than were envisaged—or experienced—when many of the older stations still in commission were designed, and the surge tank now has to be regarded as a vital element in the chain of mechanism for obtaining a quick and simple adjustment of the load. Further, the advent of the underground station has given rise to new and difficult hydrodynamic problems, and the multiplicity of surge-tank designs, both for surface and for underground stations, reflects an increasing awareness of the complexity of the factors involved.

At the beginning of his paper, Dr. Jaeger distinguishes between water hammer, which consists of elastic shock waves having a periodicity of a few seconds, and surges, which have a periodicity of 100 to 500 seconds and can be calculated on the assumption that the water and pressure tunnel are non-elastic. Most of the paper is concerned with the problems of surges although a brief section is devoted to water hammer.

Surge analysis is based on the following fundamental equations, viz., the equation of continuity:—

$$wf = F\frac{dz}{dt} + Q \quad . \quad . \quad . \quad (1)$$

and the dynamic equation: —

$$\frac{L}{g}\frac{dw}{dt} + z \pm Pw^2 = 0 \quad . \quad . \quad (2)$$

where

F = horizontal area of surge tank
f = cross-sectional area of pressure tunnel
L = length of tunnel
P = friction constant
Q = discharge through turbines
w = velocity in tunnel
z = height of oscillating level in surge tank above static level

The theory of surges was originally developed regardless of the effect of turbine governing, but it was found that some surge tanks developed unstable oscillations due to the action of the governor. Actually the governor tries to ensure a constant output N_o so that

$$N_o = \eta_o H_o Q_o = \eta (H + z) Q = \text{constant} \quad (3)$$

where H is the gross head and H_o the net head, and this forces an increased surge.

By combining equations (1) (2) and (3) and neglecting terms higher than the second order the final equation is of the type

$$\frac{d^2x}{dt^2} + 2a\frac{dx}{dt} + bx = 0 \quad . \quad . \quad (4)$$

where $x = Pw_o^2 + z$ and a and b are constants if the oscillations are assumed to be infinitely small. The oscillation are stable if $a>0$ and $b>0$, and by substituting the real values of these constants we get the well-known condition of Thoma:—

$$F \geq F_{Th} = \frac{w_o^2}{2g} \cdot \frac{Lf}{Pw_o^2 H_o}$$

Usually a factor of safety n is introduced such that $F = nF_{Th}$ where $n>1$. For years the discussion went on to determine the appropriate value for n, but Dr. Jaeger considers that a more useful approach is to calculate, by step-by-step methods, the curve of z against time and to determine the cyclic decrement $\Delta = x_{i+1}/x_i$, the condition of Thoma being fulfilled if $\Delta<1$.

Special Types of Tank

Equation (2) shows clearly that the greater the variation of z the greater will be the acceleration or retardation dw/dt of the water discharge in the pressure tunnel, and thus the more immediate will be the effect of the surge tank. Several special designs have therefore been developed to obtain a rapid increase in the value of z at the commencement of oscillation. In the variable-section tank (Fig. 1) this is achieved by a central shaft which has a diameter as small as possible consistent with the condition of Thoma, but extreme surges are limited by an expansion chamber at the top and a reservoir chamber at the bottom. The differential chamber (Figs. 2 and 4) achieves the same objectives by employing a narrow inner riser connected at the bottom by orifices to the surrounding main chamber and open at the top so that an extreme surge can spill over into the main chamber. In the throttled surge tank (Fig. 3) a constriction at the base induces additional losses Rv^2 which are added to the friction losses Pw^2 and thus reduce the surge amplitude, or alternatively enable the size of the chamber to be reduced.

An analysis of recent projects and designs shows that combined systems of surge chambers with two or more shafts, having restricted orifices, expansion chambers, overflows, and reservoir chambers, have been proposed. The aim is to reduce the overall volume of excavation and to make the design of the chamber suitable for the constructional methods used for steel-lined pressure shafts which sometimes replace the conventional pipelines. Typical examples are the Innertkirchen, Lavey and Isère-Arc installations.*

Underground stations

Underground stations introduce problems not encountered with surface stations. There are several types of underground station which, so far as hydrodynamics are concerned, behave quite differently one from another (Fig. 5). In some instances (Fig. 5a) the tailrace will be a free-flow tunnel, with the possibility

*See WATER POWER, August 1952, page 301, for Isère-Arc.

of translatory waves being formed on the surface of the free-flowing water in response to variations of the discharge as required by the changes of electrical load. There is then no departure from the conventional hydrodynamic system for above-ground conditions. In some instances the tunnel downstream of the turbines will be under pressure wholly or intermittently or partially. There are instances (Fig. 5b) when the tunnel is always under pressure, for conditions of steady flow as well as for those of unsteady flow.

In other instances (Fig. 5d) the tunnel may be normally a free-flow one and such that it works under pressure when the downstream river level rises (floods) or when the discharge in the tunnel varies rapidly.

In most of these instances, a proper surge chamber has to be incorporated on the downstream side of the turbine, so as to minimise the water hammer and the pressure variations, and to make turbine governing practicable. Fig. 5e shows a system under pressure without any surge tank being necessary because of the short pressure conduits. The hydrodynamics vary widely with the type of system, and special care has to be taken when dealing with underground systems.

Hydrodynamic conditions may be altered completely if there are both upstream and downstream surge tanks (Fig. 5c), or systems of surge tanks, the turbines

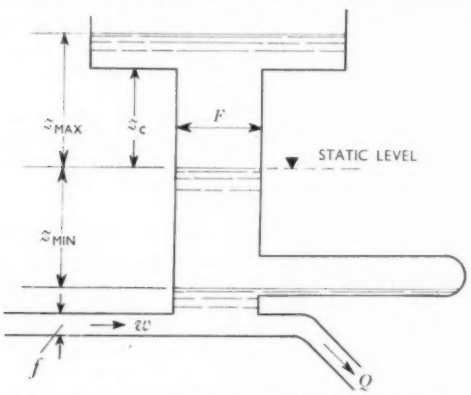

Fig. 1. Surge tank with variable section F

between being of the reaction type. This arrangement, if not carefully designed, may readily lead to conditions of unstable surge.

Loading Conditions

The increasing severity of loading conditions has had an important bearing on surge-tank design, and

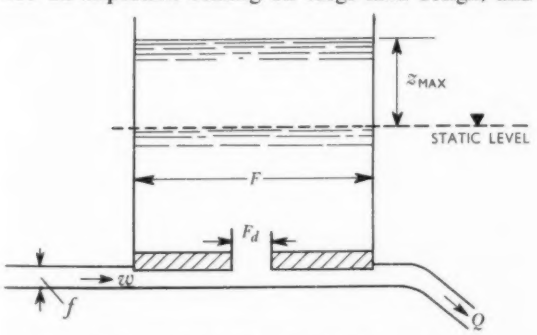

Fig. 2. Surge tank with restricted orifice

as an instance of the effects of this change the author refers to the accident at Albula station, Zurich. This station was built in 1907-1910 with eight 3,000 h.p. Francis turbines. The surge tank was correctly designed for rejection of full load, but it was assumed that the load would be taken on by opening up the turbines in succession. Later this station was interconnected with other much larger plants, and about midnight on the night of the accident Albula suddenly had to take over from another station. At 5.30 a.m. the load was thrown off abruptly, and the resultant surges were sufficient to burst the pipeline.

The lessons learnt by this disaster were applied to the design of the Innertkirchen surge chamber, which can deal with exceptional cases of superposition of surges and is extremely efficient in damping. Italian engineers have reached similar conclusions.

In a station coupled to an electrical grid there are many conditions that, in default of adequate design, might lead to dangerous surges. Any surge tank may have to cope with the sudden closing of all the turbines from full gate in the event of a short circuit on full load. Until recently it was considered that the

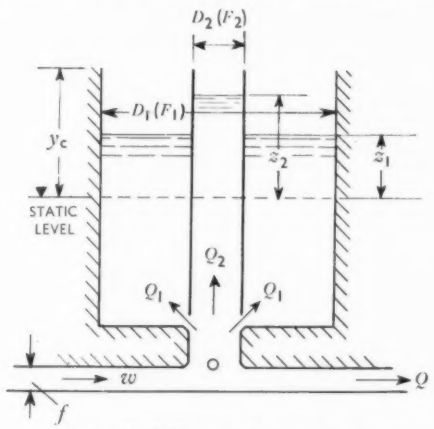

Fig. 3. Differential surge tank

conditions for taking up load were in the hands of the station supervisor, but most specialists today consider that this does not cover the more dangerous cases, as it is always possible for a station to be suddenly isolated and subjected immediately to heavy load. Further, a sudden increase of load immediately after the station has been losing load, or a sudden

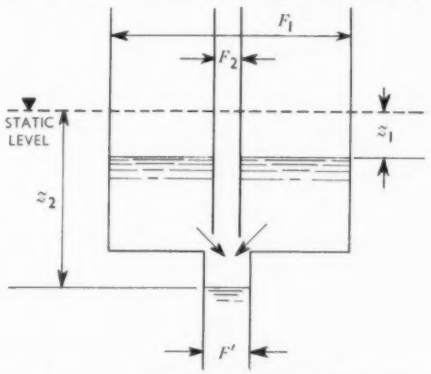

Fig. 4. Differential chamber for upper part of surge tank

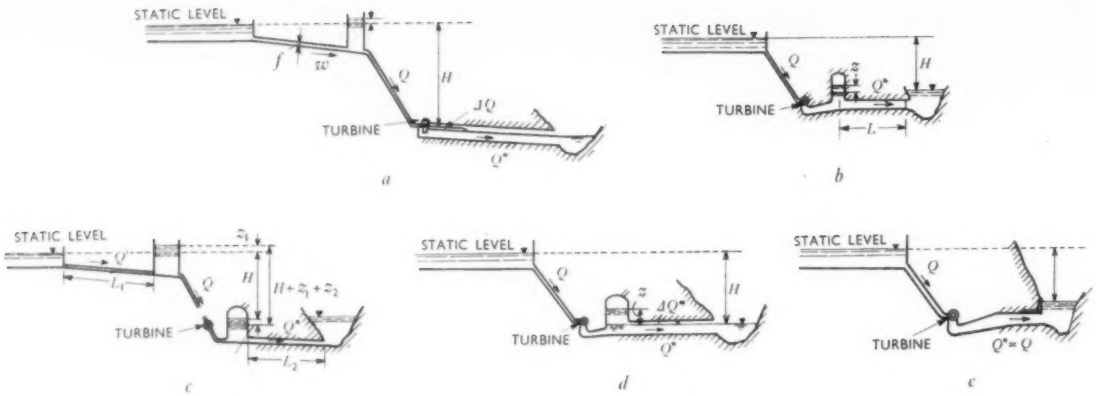

Fig. 5. The five principal types of underground power station

shut-down after load has been building up, may cause the superposition of surges. In many hydraulic systems the surges die out slowly, and surge superposition becomes correspondingly more likely. If the period of surge is comparable with the time required to synchronise a turbine, the final surge, after all the turbines have been successively synchronised, may not be much less than if all the turbines had been put on load together. In all cases it is important to investigate the downward surges as they may be even more dangerous than the upward ones.

On the other hand Electricité de France finds that in view of the extensive interconnection of its electrical system, load variations have rarely put a dangerous strain on any individual station. Its surge tanks are therefore to be designed for throwing off full load, the negative surges thus produced being analysed as well as the preceding positive surges. It will be assumed that any negative surge produced by taking on load will be limited to a reasonable amount consistent with the case of full load off. Nevertheless, these rules have the proviso that any new station shall be assessed on its individual circumstances.

Special Stability Problems

In the theory of Thoma several restrictive assumptions have been made. The surges are supposed to be very small, all terms superior to the second order having been neglected; furthermore, the governor is assumed to maintain the output N rigidly at a constant value. The station efficiency is assumed to be constant. Finally the station is supposed to be running alone on the grid with no possible interference from other stations. In practice, it may be that none of these assumptions will be correct, and further investigations may become necessary to ascertain how surge tanks behave under conditions where this is so, and to establish why they do sometimes behave differently from the manner forecast by the theory of Thoma. The whole problem requires more comprehesive treatment.

Mathematical investigations to apply the theory of Thoma to large oscillations have shown large oscillations to be stable if F_{Th} be increased by the factor

$$\left(1+0{\cdot}482\ \frac{Zx}{H-Pw_o^2}\right)$$

This formula agrees point by point with the results of detailed calculations. In some instances damping has been more efficient than is indicated by the formula, obviously because large oscillations introduce additional friction losses when the water is diverted from the pressure tunnel into the surge tank.

With regard to throttled surge tanks the author refers to the work of Escande, recorded in our June 1952 issue, who concludes that when $2p_oh_o<1$ (the condition of Thoma not being observed) stable but undamped oscillations will occur. Dr. Jaeger points out that these oscillations may prove objectionable, and there is a strong case for observing the condition of Thoma for a throttled surge tank.

No theory of the stability conditions for differential surge tanks has yet been established, but it can be shown that the theory of the ordinary throttled tank provides the key to part of the theory for differential surge tanks.

In some instances, where the orifice at the base of the inner riser is large, the differential surge tank behaves as an ordinary throttled surge tank. There is no spilling, or only a negligible quantity, over the inner riser, the maximum surge being identical with the surge in a throttled surge tank. In such a case, the condition of Thoma refers to the area of the outer reservoir, F_1, and when this condition is not satisfied for small oscillations, a state of equilibrium may be reached with large oscillations occurring similarly to those in throttled surge tanks with too small an area ($F<F_{Th}$). The conditions for the downward surge should be identical with those for the upward surge, from which the minimum height of the tank may be calculated. Instances may occur (when $2p_oh_o<1$) where this total height becomes greater than the first surges for closing and for opening added together.

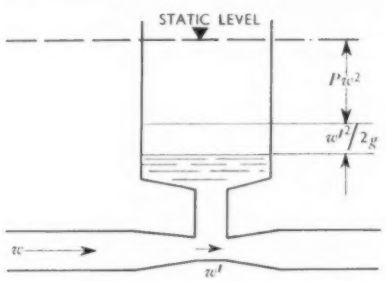

Fig. 6. Surge tank with restricted orifice and venturi effect

When the area of the restricted orifice is small and the throttling of the water passing into the outer chamber is effective, the water will reach the top of the inner riser and will spill over during the first period of the rising surge. The limit of the upward surge is then virtually equal to the height of the inner riser. A similar limit does not, however, exist for the downward surge. The diameter, D_2, of the inner riser can no longer be neglected when the damping of the oscillations is being considered, and there is an obvious danger of unstable oscillations in the downward direction.

Full stability will certainly be obtained when the area F_2 of the inner riser satisfies the condition of Thoma. Differential surge tanks connected to high-head plants are likely to fulfil this condition and to be stable. Others, especially those connected to low-head plants, may be unstable.

When the surge tank is on the upstream side of the turbines, the velocity head $w_o^2/2g$ can be added to the friction losses, and the quantity

$$P' w_o^2 = \frac{w_o^2}{2g} + P w_o^2 = \left(\frac{1}{2g} + P\right) w_o^2$$

will appear in the denominator in the formula of Thoma instead of Pw_o^2. Furthermore, this $w_o^2/2g$ is not lost, for the net head should include this amount.

When the head is low and the tunnel short, this theoretical effect of $w_o^2/2g$ may be very considerable, and it has been proposed to increase the damping by introducing a venturi effect in the form of converging cone and an expanding taper pipe at the bottom of the surge tank, as illustrated in Fig. 6, where this is shown in association with a throttled surge tank.

The efficiency of such an arrangement can be tested on a model. On the other hand, experience with models shows that, when the water in the tank is low, its surface may be quite unsteady with unexpected passages from the piezometric level to the energy level. These are indications that perhaps only part of the $w_o^2/2g$ is effective in damping the surges.

When dealing with the stability of systems of surge tanks the author outlines the following rules summarising roughly the main results (obtained from the general theorem of Hurwitz on stable oscillations) when two surge tanks are connected to the same pressure tunnel on the upstream side of the turbine:—

If the surge shaft nearer the turbines satisfies the condition of Thoma ($F_2 \geq F_{Th}$) the system will be stable, whatever the dimensions of the second surge tank.

If the nearer surge tank is smaller than the area indicated by Thoma, but larger than half this area ($\frac{1}{2}F_{Th} < F_2 < F_{Th}$) then the sum of the areas of the two surge tanks ($F_1 + F_2$) will have to be larger than F_{Th}. If the second surge tank is close to the nearer one, then a small margin of the total areas above F_{Th} may be sufficient to secure stability of the system. If the second surge tank is nearer the tunnel intake, then its area will have to be very considerable and the proper solution will be adherence to the rule of Thoma for the lower surge tank.

The rules giving the minimum permissible area of F_1 and F_2 as a function of their location are involved.

When the turbine is a reaction wheel with surge tanks on both the upstream and the downstream sides, it does not seem possible to apply the general rule of Hurwitz. Studies yield a somewhat different theory with the result that, owing to mutual interference of the oscillations in the upstream and the downstream tanks, the limiting value given by Thoma has to be greatly exceeded. These results have been checked by direct calculations.

Considering the effect of interconnection of power stations it can be shown that when any station supplies less than one-third of the load its surge tank will always be stable. Thus, when it is desired to test a station for surge stability, the station must be isolated and loaded from a limited grid or water resistance. If the station is liable to become isolated the condition of Thoma should be observed at all costs.

An interesting table is given in the paper relating to stability tests on five stations all of which are provided with surge chambers not complying with the condition of Thoma. In some cases markedly or dangerously unstable oscillations were produced, but in other cases the oscillations were stable. Reference is made to detailed studies of these cases, but only provisional conclusions can be drawn. Nevertheless it appears that the turbine governor characteristics may have a marked effect in promoting or interfering with stability, and additional throttling losses and variations in turbine efficiency may also have an influence.

Dr. Jaeger's summing up of the stability problem is worth quoting verbatim:—

"In spite of being disputed, this simple formula of Thoma remains a most important criterion for designers. When allowance is made for all latter-day results, confidence in this formula is not greatly impaired. It does not matter so much to know whether the mathematical instability of the surges begins for an F value slightly smaller than or just equal to F_{Th}. It is known definitely that for $F = F_{Th}$ the surge amplitude may reach disquieting values. The designer should be more interested in the decrement $\Delta = x_{i+1}/x_i$ of these surges. A theoretical formula which is corroborated by many direct step-by-step calculations (graphical or analytical), as well as by site measurements, shows that Δ depends primarily on the tunnel characteristics—length, cross-sectional area, roughness of the walls, and total friction losses. For surge tank design, the right estimate of Δ is of great importance. Furthermore, there is definitely a link between the problem of surge stability defined by Δ and the assumptions concerning the dangerous loading conditions, which also depend on Δ. Finally, the correlations between the decrement Δ of the surge oscillations and the frequency variations on the electrical network should be studied closely."

In a brief treatment of water hammer the author states that in most instances the surge tank conveniently protects the pressure tunnel against positive and negative pressure waves, but a few exceptions occur, particularly where the surge tank is a long inclined pipe with a diameter comparable to that of the penstock or tunnel.

It is essential to check the dynamic pressure drop at the valve house, downstream of the surge tank. It is a common error of design to locate the valve house at too high a level, where surges and water hammer combined may produce pressures below atmospheric. Water-hammer wave reflection needs to be specially watched in the case of throttled surge tanks.

Finally, the paper contains a brief reference to stations the penstocks of which are supplied through open canals and free-flow tunnels.

Rainfall Stimulation for Hydro-Electric Power

Control of rainfall has been sought by man since civilisation began, and this article discusses what is being done in America to secure, in some measure, such a control.

By WALLACE E. HOWELL

THE production of hydro-electric power requires many other things as well as water, such as enormous capital investment, the execution of engineering works that stand among the largest and most difficult in the world, and management that has the vision to plan for decades in advance. But water, regulated and harnessed though it may be, remains the beginning of hydro power development and sets the limit of its size. Water is the senior member of the partnership.

For that same water, mankind has always had to depend upon the bounties of nature. A natural resource that is perpetually renewed, running water is nevertheless one of the more variable elements in our environment. The dual afflictions of flood and drought can be greatly alleviated by the construction of storage reservoirs, but a reservoir contributes no additional water and, in fact, dissipates its contents constantly by evaporation. There is not a climate in the world free from troublesome fluctuations in rainfall and run-off, some more or less predictable because of seasonal characteristics, but others defying any useful degree of prediction. Furthermore, these fluctuations are so great that the mean flow of a river is often many times its minimum flow, and its peak flow many times its mean flow.

Control over rainfall has been sought since the beginning of civilization. In the past, however, the magicians and pseudo-scientists fared far better than scientists and engineers, for they relied on the dependable rule that it always rains at the end of every drought.

It is no wonder, then, that the discovery in 1946 of a sound scientific basis for stimulating rainfall captured the public imagination and aroused widespread interest. During the past seven years this interest has ripened and developed to the point where stimulation is now being used in a large number of places to supplement natural rainfall. In short, the witch doctor has given way to the meteorologist, and stimulation of water at its source in the atmosphere has joined the ancient engineering sciences in the task of obtaining power from natural sources.

Rainmaking Science

Each scientific discovery grows out of and is made possible by the fruits of previous researches that often go back for many years. So it is with rainfall stimulation; though it burst upon the world wholly unexpectedly, the way toward it had been in preparation for a long time.

One of the first steps toward it, curiously enough,

Fig. 1. Dr. Wallace E. Howell examining rainfall data

was attainment of an understanding of why some clouds do *not* yield rain. Careful observation and measurement of the constitution of clouds revealed that the great preponderance of them is composed of water droplets too small to fall—droplets so small that it requires several hundred million of them to equal a teaspoonful of water. A cloud of this sort is colloidally stable, and it will not precipitate and release rain unless the stability is in some manner destroyed. Indeed, the large majority of clouds go through their entire life cycle from formation to dissipation without releasing a single raindrop.

Thus it became the objective of further research to determine, not the difference between precipitating and non-precipitating clouds, but how any cloud can precipitate in the first place. Various possible explanations were studied and rejected one by one; collisions due to random motions of the droplets,

Fig. 2. In one of the earliest experiments on the seeding of clouds, an observer at Mt. Washington, New Hampshire, holds a piece of dry ice in his hand and converts a cloud into a snow flurry as it passes the summit

different electric charges causing droplets to be drawn together, differing droplet temperatures to cause differential growth. None of these was found capable of causing precipitation.

The first break in the mystery came about a quarter century ago, with the discovery that ice is the important material in causing a cloud to precipitate. Under most circumstances in the temperature latitudes, no rainfall of any consequence occurs until a part of the cloud cools to a temperature substantially below freezing. In so cooling, the cloud at first remains liquid, though supercooled. At temperatures ranging from about minus 15° F. downwards, dust particles in the atmosphere begin to become active as ice-forming nuclei, and those within the cloud become the germs of snowflakes. Once started, the snowflakes grow rapidly and the surrounding cloud droplets evaporate, yielding their substance to the ice phase. The transformation of the cloud in this fashion satisfactorily explains the formation of snow and rain.

The rain-stimulation jackpot was hit in the course of the quest for further understanding of the particles that act as ice-forming nuclei in the atmosphere. Dr. Vincent J. Schaefer, of the General Electric Research Laboratory, developed a simple means of forming a supercooled cloud in the laboratory that closely duplicated the composition of natural clouds, and this laboratory cloud he subjected to tests with foreign particles of many sorts, but without much success in finding materials capable of inducing ice formation. Then one day, when his cloud box got too warm he dropped in a large piece of dry ice to cool it, and immediately observed complete conversion of the cloud to miniature snowflakes. This discovery he communicated to Dr. Langmuir, then associate director of the General Electric laboratory, with the remark, "Well, Boss, now I know how to make it snow!" And make it snow he did, proving out his laboratory results a few months later by dropping dry ice on a cloud over the Berkshire Hills and dissolving it into a few trails of falling snow.

The dry ice worked, Schaefer found, by chilling the air that contacted it below a critical temperature at which ice crystals form spontaneously without the need for a crystal germ. A single quarter-inch pellet of dry ice dropped into a cloud leaves behind it tiny ice crystals numbering in the hundreds of millions, enough so that the resulting precipitation is limited not by the number of ice germs but by the amount of cloud through which they are spread by turbulence before they fall out, and by the amount of water available for their growth.

Dr. Bernard Vonnegut, another researcher at the General Electric Company laboratory, set out on a methodical search for crystalline substances that would so nearly duplicate ice crystals as to serve as germs for snowflake growth. He came up with silver iodide, the crystals of which so nearly match ice that

Fig. 3. In one of the early experiments on Mt. Washington, New Hampshire, a piece of dry ice, approximately a 1-inch cube, was placed on the tower at Mt. Washington Observatory. Here the sun striking through from the rear shows up the dense cloud of ice crystals formed in the air blowing past the bit of dry ice. This phenomenon is possible only in air that is supersaturated with respect to ice

Fig. 4. Rain stimulation activities in Cuba. A silver iodide smoke generator is set up alongside a sugar cane hoist. On many Cuban projects, a track car such as the one shown, is used for transporting generators to the spots where operations are ordered according to the daily weather situations

they "fool" water vapour into crystallizing at a temperature of about 23° F., far warmer than the usual limits of natural snow-crystal formation in clouds. Furthermore, he demonstrated a method of producing a smoke of silver iodide crystals so finely subdivided that a few milligrams of the chemical can seed a cubic mile of cloud and convert it to snow.

Measurements made atop Mount Washington for the past several years show that the concentration of natural ice-forming nuclei in the atmosphere fluctuates very widely and is frequently very low for extended periods of time. Furthermore, the frequent occurrence of widespread supercooled cloud sheets from which no snow falls indicates that there must be sizeable regions of the atmosphere lacking in these nuclei. The discoveries of Schaefer and Vonnegut mean, not only that the deficiencies can be overcome by artificial means, but that vast numbers of nuclei can be introduced into the air that are effective at a higher temperature, hence (in general) sooner and through a larger volume of the atmosphere than are the natural nuclei. In this way, cloud seeding predisposes the atmosphere to precipitate as soon as other necessary conditions are met.

In tropical areas, where clouds may become extraordinarily rich in condensed water before their tops reach the freezing level, rain is sometimes set off by a second agglomerating mechanism. Especially in maritime locations, the air has been found to contain, in addition to the ubiquitous condensation nuclei of very small size, a few relatively large particles of salt that are capable, within these clouds, of forming droplets by deliquescence that sometimes grow to be as much as 50 microns in diameter. Once they have reached this size, they begin to have a falling speed large enough to bring them into collision with other cloud drops, causing them to grow by accretion and become raindrops. The raindrops thus formed initially may become so large that they break up into smaller drops, each of which grows and breaks up to perpetuate a chain reaction sweeping the cloud's water down in the form of a rainshower. This growth by accretion occurs in clouds outside the tropics, too, once the first few precipitation particles have formed; but it is only in the tropics that conditions are right for these essential first few particles to form without the intervention of ice-forming nuclei. Inoculation of dense water-clouds with large water droplets has shown that, in these clouds too, the natural rainmaking processes can be effectively triggered by artificial means—by seeding with water droplets or salt particles of the right size.

On the basis of what is known about the physics of precipitation, it is to be expected that cloud seeding will produce precipitation when weather conditions approach those for natural precipitation, and increase the amount when precipitation would have fallen anyway. The present status of the science does not enable one to predict, on a theoretical basis alone, how large the effect should be. The answer to the

Fig. 5. In Peru, studies in connection with rainfall stimulation included measurements of snow melt on glaciers over 16,000 feet above sea level in the High Andes. Here, a camp is established at the foot of one of the glaciers of Mt. Huagaruancha

Fig. 6. Working on a glacier on the slopes of Mt. Huagaruancha, an observer prepares a lysimeter for measurement of the snow melt at the surface of the glacier

questions, when and how much, must be sought, for the present, in the results of experience with cloud seeding. The second and concluding article of this series will present the material bearing on these important questions.

Rainmaking Clients

In the first flush of enthusiasm about reports of successful rain stimulation, it was conjectured that this new art would have its main usefulness in watering arid or semi-arid regions such as the American desert, the grazing lands around the borders of the Sahara, and the often drought-ridden lands of the Middle East. As a matter of fact, however, the applications have followed a different but perfectly sensible pattern. " Rainmaking " has been most successful and most widely applied where the total production of value based on water is largest, and not necessarily where water has the highest value per unit of measure. For example, extensive rain stimulation activities have been carried on in a region of eastern Canada where water is so plentiful that the area is distinguished by its liberal supply of lakes and swamps—the reason being that these lakes feed the largest privately owned hydroelectric development in the world, and additional water there has quickly convertible cash value in the form of refined aluminium. The rainiest state in the United States is Louisiana, and here too a large corporation has turned to rainmaking to protect its agricultural and

industrial interest in water. The same general reasoning holds in the tropics, where rainfall stimulation has been applied on an expanding scale, even in climates having natural rainfall of nearly 60 inches annually, because of the presence of large-scale intensive agriculture—sugar cane—that is intimately dependent upon water for productivity. Many more examples could be quoted, all having in common the loss of needed productivity when natural supplies of water fall below the requirements for maximum productivity. Potential benefits for arid lands still exist, but such lands require the integrated development of increased productivity, involving complex social and commercial changes, that must go along with rain stimulation before the potential value of the latter can be realised, a situation that will tend to complicate its application.

Fig. 7. At a meteorological station established on the continental divide in Peru a silver iodide smoke generator goes to work while observers keep an eye on cloud developments

For the most part, the leaders in backing the practical application of rain stimulation for industry, agriculture, and other uses have been corporate entities that control or have interests concentrated in an area ranging in size from fifty or a hundred square miles on up to several tens of thousands of square miles. Some are cities controlling large watersheds for domestic water supply, others are hydro-electric companies, and yet others are agricultural concerns or integrated water users such as the pulp and paper companies, which depend on water for tree growth, for driving the logs to the mill, for the process water at the mill, and as a source of power. In addition, there has been some success in organising "weather improvement associations" among farmers and even among incorporated townships and counties in the farming states, for the sake of contracting for rain stimulation services, but difficulties have been quite apparent in keeping these associations from dissolving due to internal stresses.

Particularly in the case of the larger corporations, attention was directed toward the possibilities of rain stimulation through keen awareness of the hydrologic situation, and many of them have long kept weather records and even maintained hydrologists on their staffs to aid them in making the best use of their water resources. It has been in general those companies best informed about their water resources, the ones that can most easily attach a value figure to them, that have led the way in undertaking practical rain stimulation.

Rainmaking in the Field

The conception and gestation of a rainfall stimulation project, before it is ready to be launched, requires, of course, digestion of the hydrologic information in terms of the economic penalties suffered from lack of water or the values that can be realised from additional water. Beyond this, however, it requires integration of these data with the broader point view of synoptic climatology and physical meteorology, the study of the patterns of daily weather that combine to create the climate and the processes by which the climate functions, for it is the daily functioning of the weather that must be dealt with in the field. These considerations, in turn, must be viewed in the light of experience with the field operations required for cloud seeding on a commercial scale, including such matters as accessibility, communications, and supply. It is at this point that the professional "rainmaker" enters the picture.

The planning stage of a new project begins with a careful review of the available climatic information and interpretation of it in terms of synoptic climatology. From experience gained with seeding in various weather situations, an estimate can then be made of the prospective results of the programme. When unfamiliar territory is under consideration, the study is normally combined with a field survey that includes study of local meteorological peculiarities of the area under consideration and the practical aspects of operation within it, such as road and telephone networks, suitable operating points, etc.

Upon completion of the study, with all the pertinent facts available, a conference between the sponsors of the project and the meteorological engineers conducting it establishes the pattern that operations are to follow. In most cases, all phases of the actual operation are carried out by the meteorological firm. In some cases, especially abroad, where the sponsoring company often has extensive facilities in the field, it works out to best advantage for it to provide unskilled labour, and sometimes transportation and communications available within its customary practices. The meteorological consultants still provide the technical equipment and supplies, professional meteorological services, and close supervision of the field operations.

At this stage in the proceedings it is essential that all parties be aware of the limitations—on the one hand, limitations as to what rainmaking can and cannot do, on the other hand limitations imposed by

terrain conditions and operating facilities.

Usually, the establishment of the project in operation is simple and straightforward. A field meteorologist takes charge of the project. Operating sites are prepared, which may be anything from a corner gasoline station where a mechanic can act part-time as generator operator, to an observatory established for the purpose on a mountain top, or a camp established by air on a remote lake and manned by two operators so that if one man is incapacitated by an accident the other can summon help. Or the generator may be operated on a portable basis, being stationed by motor vehicles on a day-to-day basis. Equipment and supplies are distributed, communications schedules are set up that bring up-to-the-minutes weather information to the field meteorologist and enable him to pass on his instructions to the generator operators. The first mission plan goes out, the smoke generators fire up, and the project is under way.

Fig. 8. Silver iodide smoke generators and supplies are loaded into an airplane for transportation to remote operating sites in Quebec

The daily routine starts with an estimate of the meteorological situation, based on continuing analysis of weather data as it arrives at the home office or the regional meteorological office. On the basis of this estimate, information for mission planning is sent to the project meteorologist, who completes his mission plan for the day and sets it into operation. Later in the day, a second estimate is made, on the basis of which a preliminary mission plan for the following day is prepared and operating personnel alerted accordingly. Meanwhile, the project meteorologist is in a position to make last-minute emendations on the mission plan to take advantage of local situations that he observes developing, or to correct for occasional inaccurate forecasts.

Another essential part of the project meteorologist's job is the assembly of the rainfall records from the target area and surrounding regions for use in computing the degree of stimulation achieved, and in studying the effectiveness of the day-by-day operations as a check on the quality of the meteorological estimates and the mission plans. These activities, together with the preliminary hydrologic and climatological studies accomplished during the planning stage, lay the groundwork for an evaluation of the physical results achieved by the operations, an evaluation aimed at determining the amount of the stimulation produced and the degree of confidence to be placed in the expression of this amount. This evaluation constitutes among the most complex and challenging parts of the meteorologist's work in connection with rainfall stimulation. A second article of this series, will review the results achieved in commercial rainfall stimulation projects and discuss the problems relating to the evaluation of them.

(To be continued)

Fig. 9. Supplies brought in by boat for the establishment of wilderness stations are laid out on the beach and checked over, preparatory to the establishment of camps to be taken in by air

Location of power plants in Soviet-dominated Europe

Behind the Iron Curtain

We are indebted to the Italian Edison Group* for the following information on hydro-electric development behind the iron curtain, which is reproduced from a comprehensive survey of the electricity industry in the Eastern-European countries under Soviet control.

OWING to their geophysical structure, the Eastern-European countries present in common the rather paradoxical feature of a scanty hydro-electric development in an area abundantly watered by such major streams as the Danube, Oder and Vistula, together with their tributaries. As a whole, this vast tract of land, considered in relation to its area, cannot be said to have an excessively rugged surface. In the north, the huge plains of the Oder and Vistula extend, in Poland, from the Baltic Sea to the Galician and Silesian Hills, while, farther to the west, the ranges of the Sudetes, Giant and Ore Mountains, Bohemian Forest, and Moravian Hills form the border of Bohemia and Moravia. Turning now to the east and south-east, we find the Carpathians, Transylvanian Alps, Balkans and Rhodope in an almost uninterrupted range, which at the Iron Gate, near Orsova on the Danube, separates the Hungarian from the Walachian plains in Southern Rumania, through which the Danube flows into the Black Sea. The average annual precipitation is abundant and reaches a maximum in the summer in the central-eastern region of Europe, and in the spring in the Carpatho-Danubian and Balkanic regions. The rivers, especially the main streams, are moreover characteristic flat-country watercourses, well distributed on the whole, which rise to their maximum discharge in the spring, when thaw sets in.

Before the water-power resources available in each country are reviewed, three large-scale projects should be mentioned since they are more or less closely connected with hydro-electric development:—

(a) The Danube-Oder canal across Morava, proposed as far back as the beginning of this century but subsequently shelved, when the two countries interested, Germany and the late Austro-Hungarian Empire, failed to reach agreement. The project emerged again, this time with Hitler's Reich as sole partner, in 1939-40, and work on it was in progress but had to be deferred because of the war. Now, under Soviet management, the project has come again to the fore, and things have moved so far that construction work is scheduled to begin in 1956 and the canal is expected to be in commission by 1964.

(b) The Danube/Black Sea canal in Rumania, now at an advanced stage of construction, which will shorten the navigation route by 450 km. This canal, 76 km. in length, and varying in depth between 6 and 8 m., is to be inaugurated next year.

(c) The Vistula project, which is the most extensive of the three, and its construction is expected to take about 30 years. It comprises a vast programme of works for the improvement of navigation on the river, a canal on its upper course to connect with the Oder, an improved connection with the Dnieper, and the construction of some ten hydro-electric power plants to ensure yearly an additional production of 2,000 million kWh, not to mention the benefit of irrigation to an area of 740,000 acres.

Of all the satellite countries, Rumania is richest in absolute water resources (21,600 million kWh p.a.) but remains behind Albania in relation to area (91,000 against 104,500 kWh per sq. km.). The central region and the region of the Transylvanian Alps are best adapted to the utilisation of these resources. The present scale of utilisation is still minimal but great efforts are being made to improve adequately this position within the frame of the Five-Year Plan. In addition to seven large thermal plants, hydro-electric plants are in course of construction at Corbeni, Dragan-Remetzi, Oureni, Sadu and Moroieni. Since 1950, the Bistritza-Stejar ("V. J. Lenin Plant") and Marveni hydro-plants have been completed.

Czechoslovak resources (7,000 million kWh p.a., 54,700 kWh per sq. km.) are harnessed to a fairly wide extent. Conditions for hydro-electric development are particularly favourable in the Bohemian Forest, Moravian Hills and Sudetes, while in Slovakia high heads are available and await development on the Vah, Hron-Sajo and Dunajec rivers in the Tatras. The Kostolna plant, near Trentshin on the Vah, and the Orava station in the Tatras were completed last year. The most important developments under construction, all on the Vltava, are at Vyssí Brod and Lipno, on the upper course of the river in the Bohemian Forest, and at Slapy, largest installation of all, with a dam which will raise the level of the Vltava and create a lake about 43 km. in length just upstream of Prague.

Bulgaria's restricted resources (6,000 million kWh, 54,100 kWh per sq. km.) are utilised to a rather small extent, in spite of the fact that water constitutes the sole appreciable source of energy in the country. The important Maritza system is in the south, while, in the north, the rivers flowing into the Danube from the northern slopes of the Balkans could be developed to a fairly wide extent. Since 1950, the following plants have been put into service: Assenitza, Tenja, Kitka, Vidima and Petrovo; the Ventcha power station is being extended, and the "Vassil Kolarov" dam has been completed. Plants in course of construction or nearing completion are at Petrohan, Medza, Sestrimo, Paja and Pchaja, together with the Rossitza, "Georges Dimitrov," "Stalin," and Studena dams.

The two Polish basins of the Vistula and Oder could contribute on a small scale to hydro-electric development in the south of the country, in Silesia and in the Cracow district as well as, in part, in the

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Lublin region. Hydraulic resources do not exceed 5,500 million kWh, available almost exclusively at low heads at the rate of about 17,600 kWh per sq. km. Several plants have either been put into commission in 1951-1952, or are being extended, such as the "Ludwik Warynski" station at Dychow, and the Poznan and Zabrze power houses.

Albania is scoured by a dense river system. Resources do not exceed 3,000 million kWh, but as mentioned in the paragraph relating to Rumania, they are distributed at the rate of 104,000 kWh per sq. km. Unfortunately, very little has been done in the matter of hydro-electric development, and the only installation worth mentionning, as far as information is available, is the "Lenin" station, north of Tirana, commissioned in 1951.

The paradoxical position underlined at the beginning of this survey is most conspicuous in Hungary, where the huge masses of water of the Danube and its tributaries offer no more hydro-electric possibilities than little Albania, that is to say 3,000 million kWh at an average of but 32,300 kWh per sq. km. The Danube alone accounts for 80 per cent. of these resources, the rest being contributed by the Tisza system. The Tiszalök plant on the Tisza is the only hydro-electric scheme included in the 1950-1954 Five-Year Plan; it is worth recording that, among the thermal plants, the Lovacsi power house is to use methane instead of coal.

Thermal generation still largely preponderates in most of the satellite countries. According to the figures given by the 1950 Economic Survey of Europe, it accounted in that year for 97·5 per cent. of the total production in Hungary, 94·7 per cent. in Poland, 90·5 per cent. in Rumania and 87·9 per cent. in Czechoslovakia. The share of water power is highest in Bulgaria (38·4 per cent.), and is bound to take the lead in not too distant a future. No similar figures are available for Albania, where industrial development is still lagging far behind the European average; it is, however, fairly safe to assume that hydraulic production is already leading there.

The following figures, extracted from the E.C.E. statistics reprinted in *Quaderni di studi e notizie*, show the increase in million kWh which has taken place between 1938 and 1950 in the hydro-electric production of the countries under review, Albania excepted:

Bulgaria	140 to 280,	i.e.	100%
Czechoslovakia	600 to 1,100,	„	83·3%
Poland	50 to 500,	„	900%
Rumania	83 to 200,	„	141%
Hungary	20 to 70,	„	250%

In spite of this general progress, consumption of electrical energy per head of the the population, with the exception of Poland and Czechoslovakia, is still very low in Eastern Europe, as shown by the figures published for 1951: Bulgaria 129 kWh, Albania 153 kWh, Rumania 161 kWh, Hungary 333 kWh, Poland 444 kWh, Czechoslovakia 786 kWh. These figures give an accurate picture of the degree of industrialisation in the various countries surveyed, and the share of water power in the consumption of electricity is probably highest in Bulgaria and Albania.

Water Power in Labrador

Until the war Labrador was more or less undeveloped and largely regarded as being too remote, too wild and too difficult to tame easily. But during the war the construction of the Goose Bay airport opened up the country from the air, and the post-war formation of a powerful new British company to participate in the development of the natural resources of Newfoundland and Labrador has once more turned the spotlight on the vast potential water power of this part of Canada.

The new company, which was set up a few months ago and whose formation was ratified by Provincial Legislature at the end of April, is the British Newfoundland Corporation. A syndicate of about twenty major British industrial, banking and insurance firms, the new corporation has been granted wide mineral, timber and water power concessions in Newfoundland and Labrador. It follows the setting up, in 1951, of the Newfoundland and Labrador Corporation, which is a Crown company comprised of the Newfoundland Government and private United States and Canadian interests.

The Federal Department of Resources and Development is now collecting basic information on a number of rivers. At Grand Falls on the Hamilton River, for instance, the river descends 315 ft. and estimates of potential power it could generate have been put at 1·5 million horse power, at least. A little farther down the Hamilton River is a series of rapids which are suitable for hydro-electric development, while 100 miles farther downstream again are the Muskrat Falls, said to be capable of generating one million horsepower. These falls, about 20 miles from the Goose Bay airport, are at present under concession to the Royal Bank of Canada.

On the Unknown River are the Unknown Falls with twin drops of 90 ft. and 100 ft. These are more remote and still unsurveyed, but are considered good for about one million horse-power. Other rivers such as the Kenamu are known to have rapids and potential driving force.

Surveys in Newfoundland have disclosed the possible 500,000 horsepower capacity of four of its rivers if linked together at Bay d'Espoir. Other rivers in Newfoundland have hydro-electric possibilities though they are neither so big nor so powerful as those in Labrador. Some of the smaller rivers are already being developed by the Newfoundland Light and Power Company.

Boving Turbine Brochure. An admirably produced brochure has been issued by Boving & Co. Ltd. giving a brief history of the firm and its activities, particular attention being devoted to its outstanding achievements of recent years. The text makes interesting reading and the photographic illustrations are excellent in every way. The Francis type only is dealt with and is considered under three headings—spiral turbines, casing turbines, and open-flume turbines. An impressive list at the end of the brochure cites brief particulars of the turbines delivered since 1918.

St. Lawrence Waterway Development

A short abstract is given of a lecture which was presented to The Royal Society of Arts by J. F. Grandy, B.A., B.Phil., Office of the High Commissioner for Canada.

THE St. Lawrence and Great Lakes may best be considered as a river system which rises in the middle of the continent over 2,000 miles from the Atlantic Ocean, the first thousand miles, from Belle Isle to Montreal, being freely navigable during the open water season. The rest of the system, that is, the upper St. Lawrence river, the Great Lakes and their connecting channels, consist of freely navigable sections divided by natural obstacles which bar navigation from passing from one section to another. The main barriers are the various rapids in the St. Lawrence River itself, the Falls at Niagara, and the Rapids at Sault Ste. Marie.

It is no paradox to say that in addition to being the main obstacles to navigation in the Great Lakes—St. Lawrence system, these barriers are also its great source of wealth, for they mean significant drops in the water level, and can therefore be large sources of hydro-electric power.

There are five natural divisions of the St. Lawrence River above Montreal. The Lachine section, 24 miles long, extends from Montreal to Lake St. Louis. Within it there is a drop in water surface levels of about 48 ft., mostly between Montreal and Lachine.

The next section, the Soulanges section, 18 miles long, extends from the head of Lake St. Louis to the foot of Lake St. Francis, with a difference in water levels of about 83 feet. Here again there have been various canals, the present one being the Soulanges Canal which was completed in 1899, providing for 14 ft. navigation. There is also, however, on the south side of the river, the Beauharnois hydro-electric power canal, which has been designed for a 27 ft. channel.

Third is the Lake St. Francis section which, except for a few shoals, provides ample depth for 27 ft. navigation.

These first three sections of the river are entirely within Canadian territory, while the next two sections are bounded by the Province of Ontario in the north, and the State of New York in the south.

The fourth is the International Rapids section, which extends from the head of Lake St. Francis to about four miles east of Prescott, 47 miles long, with a drop in water level of about 92 ft. This drop is overcome by a series of five canals which now provide 14 ft. navigation.

Finally, there is the 1,000 Islands section which extends from about four miles below Prescott to Lake Ontario, about 68 miles. The channels in this section have been deepened to a depth of 27 ft.

Passing on to the obstacle presented by the Niagara River and Falls, there is the Welland Ship Canal connecting Lakes Ontario and Erie, with a difference in elevation of 327 ft. This is the fourth Welland Canal: it was completed in 1932. It contains eight locks, all of which are 80 ft. wide with 30 ft. of water on the sills. Although there is a little more dredging to be done in the canal, no further construction is needed to provide a 27 ft. depth throughout.

The channels in the Detroit River, Lake St. Clair and the St. Clair River, which connect Lake Erie with Lake Huron have been deepened progressively by the United States Government until at the present time a 20 ft. depth is available in the up-bound channels and 25 ft. in down-bound channels.

The final obstacle to free navigation was the St. Mary's River, which connects Lake Huron and Lake Superior at Sault Ste. Marie. Here there is a drop of about 21½ ft. The first canal was built in 1797. At the present time there are two canals, one on the Canadian side with a depth of 18 ft., and one on the American side meeting the same standards as the Welland Canal with 30 ft. of water on the sills.

By 1900 there was a continuous system of navigation of 14 ft. depth from the upper lakes to Montreal. Today there is still only a 14 ft. system between Prescott and Montreal, while above Prescott 20 ft. is available up-bound and 25 ft. down-bound. The only important obstacle to deep water navigation is the section between Prescott and Montreal. Although the 14 ft. system was not completed until 1900, agitation for deep water navigation was well under way by the 1890's, and the first commissions of enquiry were appointed by the United States and Canadian Governments respectively in 1895.

The 1941 agreement provided for the construction of the remaining links of a 27 ft. waterway from the head of the Great Lakes to Montreal, and for a power scheme in conjunction with the navigation works in the International Rapids section of the St. Lawrence. Leaving aside for the moment the International Rapids section, the works that remain to be done to complete the scheme envisaged are the following: some channel dredging in the upper lakes; dredging in the Welland Canal; the construction of a channel in the Lake St. Francis section; the construction of a channel, a short canal, and several bridges in the Soulanges section; and finally, the development of the Lachine section, either for navigation alone, or for navigation and power. There is a good deal of work to be done in this section, which leads into Montreal Harbour. The construction of power facilities would create a source of 1,200,000 horse-power immediately adjacent to the large industrial area around Montreal.

In the International Rapids section, the following main engineering works envisaged are: (a) a control dam in the vicinity of Iroquois Point; (b) a dam in the Long Sault Rapids at the head of Barnhart Island and two power houses, one on each side of the international boundary, at the foot of Barnhart Island; (c) a side canal to carry navigation around the control dam and another south of Barnhart Island to bypass the main Long Sault dam; (d) a number of dykes, channel enlargements and railway and highway re-

locations; and (e) the reconstruction of the village of Iroquois and part of Morrisburg, which would be inundated when the river was dammed.

The power development at Barnhart Island would make use of a drop in water level of some 90 ft. and would provide about 2,200,000 horse-power to be divided equally between the United States and Canada.

A year ago, therefore, everything was ready from the Canadian point of view for the scheme to go ahead, with the Canadian Government paying for the navigation works, and the Province of Ontario or the Hydro-Electric Power Commission of Ontario constructing and paying for the power works. An agreement had previously been concluded by the Canadian Government with the Government of Ontario to arrange this division of responsibility. In the United States, however, some administrative and legal difficulties remained. Under the Federal Power Act the Power Authority of the State of New York had to obtain a licence from the United States Federal Power Commission to develop the United States half of the power facilities in the river. This licence has actually been issued by the Commission, but the Commission's action in granting the licence has been challenged in the courts and some time may elapse in litigation before the way is completely clear for the work to proceed. In the meantime, on 12th November, 1953, the Governments of the United States and Canada concluded an agreement for the establishment of the St. Lawrence River Joint Board of Engineers. Its purpose is to review, co-ordinate and approve the detailed plans and specifications of the power works, and the programme for their construction in the International Rapids section of the river. The Board is also to ensure that the construction of the power project is in accordance with the requirements already approved by both governments and by the International Joint Commission.

If the project goes ahead in this fashion there will be certain changes of the plans embodied in the 1941 agreement. Some of the navigation works in the International Rapids section which were to be constructed on the United States side of the river will have to be built on the Canadian side, and the 27 ft. depth will be provided by the Canadian Goverment only as far as Lake Erie. This is not a very serious limitation, since from Lake Erie on to the head of the lakes the channels already provide for 20 ft. up-bound and 25 ft. down-bound, and in the future no doubt further dredging of these channels could be undertaken by either country without undue difficulty. The works to be done in the Canadian section of the St. Lawrence River need be no different under this scheme than under the other. In either case these works would have been built and paid for by Canada, whereas the navigation works in the International Section that were to have been constructed and paid for by the United States will now be carried out by Canada. The power project will be constructed jointly by the Ontario and New York agencies concerned, who will each be responsible for their own half.

It has always been particularly important in North America to provide the cheapest possible means of transportation because of the long distances that must be covered. This is perhaps even more true in Canada than in the United States. In Canada the population is smaller and local markets are often not available for most of the main products of an individual area.

When the project was first put forward, and later when the first Treaty was signed, the movement of grain from the Western prairies was by far the most important function the waterway was expected to serve. It is still one of the most important functions, but it is now expected to be surpassed in importance by the movement of iron ore from the Quebec—Labrador region through the new port of Seven Islands east of Montreal up into Lake Erie to serve the steel industry in that area. Without the St. Lawrence waterway the ore will move by sea to Baltimore for use by the Atlantic coast steel mills, or for trans-shipment by rail to Pennsylvania, but the least expensive way of getting ore from Seven Islands to Pittsburg will be through the St. Lawrence waterway. The difference in transportation costs is so significant that it is thought that when the deep waterway is in operation, the extraction of the 10 million tons of ore a year which is now planned can be doubled. The direction of this movement is particularly fortunate, for previous studies of potential traffic had had to assume a good deal of movement of shipping from east to west in ballast. It is logical to suppose that the ore carriers would now return down the system carrying coal from Pennsylvania, or else would go on to the head of the lakes after unloading their ore and return with wheat. There might very well therefore be a movement from east to west of say 15 million tons of iron ore and from west to east of something like 10 million tons of grain, and possibly four million tons of coal. Other likely products are pulp and paper, automobiles, and a number of small miscellaneous items.

The arguments against the project come from a variety of sources, many of them naturally enough organisations who believe rightly or wrongly that the opening up of the St. Lawrence to deep water navigation will be a serious threat to their own commercial interests. Some of the United States railroads and a number of Atlantic ports have played a leading role in opposing the project for reasons such as this. There have also been objections from people on budgetary grounds, people who believe that the scheme will be wildly expensive, that the final cost will prove to be two or three times what is estimated, and that the project can never pay its way, especially as it will be ice-bound five months in the year. One will notice a fundamental difference between these two arguments. If the transportation interests who think they are threatened are right in their belief, those who believe the scheme to be uneconomic must be equally wrong. Mr. Grandy expressed his own belief that the scheme would fully pay its way, but that competing forms of transportation were unlikely in the long run to suffer very much and indeed may well benefit from the increased industrial activity that the seaway will induce.

Ransomes & Rapier Limited. Publications No. 3/464 and No. 489 received from this firm deal respectively with "What we make" and the "Rapier 424," the latter piece of equipment having a $\frac{3}{8}$ cu. yard bucket that can be variously operated as a straight shovel, drag shovel, skimmer, dragline, grab crane or pile driver. Among the range of equipment now manufactured by Ransomes & Rapier Limited various forms of excavator are included, mobile cranes of all types, fork lift trucks, and a wide range of such contractors' plants as concrete batching equipment, truck mixers, tilting mixers, pan vibrators and portable self-priming pumps.

Book Reviews

Hydraulique Technique. By Charles Jaeger. Translated from the German by Marie Laronde. Dunod, 92 Rue Bonaparte, Paris VI. 1954. 510 pp. 303 ff. Price 4,900 fr.

This is a translation into French of Dr. Jaeger's monumental work "Technische Hydraulik" which was published by Verlag Birkhauser A.G., Basle, in 1949. Dr. Jaeger's standing in the hydro-electric domain is unquestioned, and his book should be of the utmost value to others in this field, for it provides a detailed and fundamental treatment of the many hydraulic problems with which the civil engineer is confronted in the design of hydro-electric works.

The book is divided into four sections: Physical Principles of Hydraulics, Continuous-Flow Problems, Transient-Flow Problems, and Flow Through Pervious Ground.

In the first section no space is wasted on elementary hydraulics but the author concentrates on matters of particular relevance to hydro-electric practice, such as laminar and turbulent flow, losses in pipes, and uniform flow in open channels.

The second section commences with an extended statement of fundamental hydrodynamic equations and proceeds to discuss the dynamics of flow in open channels. Problems in which the flow is varied either gradually or abruptly due to the slope or conformation of the channel are then studied. These include flow changes produced by the interposition of steps, submerged weirs and orifices, piers and so forth, and the section terminates with a discussion of flow over dam spillways.

The third section is the longest and one of the most important in the book, for it deals at length with the design of surge chambers, the theory of water hammer, and waves induced in open channels, concluding with a chapter on flow problems in underground power stations.

The final section deals with flow through pervious strata with special reference to the theory of Dupuit.

Dr. Jaeger's book can be regarded as a standard textbook on the fundamental hydraulics of hydro-electric schemes, and we hope that it may become possible eventually to publish an English version for the benefit of readers unfamiliar with German or French.

Vízerőhasznosítás (Water-Power Development), Vol. I, by Dr. Emil Mosonyi. Published by the School-Book Publishing Section of the Hungarian Ministry of Education. Printed by Budapest University Press. 7 in. by 9½ in., 356 pp., 241 ff., 79 plates with 135 photographic illustrations, and 5 folded diagrams in an appended portfolio. Price in Hungary, paper-wrappered 91.00 Florins, paper-board bound 112.00 Fl.

This is, to our knowledge, the first work on hydro-electric development that has reached us from beyond the iron curtain. That it comes from Hungary is somewhat surprising, since in spite of immense water resources, that country offers the smallest possibilities of water-power development among the Soviet satellites with the exception of Albania. On the other hand, this very comprehensive textbook is sound proof that Hungary, in spite of her coal resources, is devoting due attention to these possibilities.

The present first volume consists of two parts, devoted to the fundamentals of water power, and to low-head plants respectively. Judging from the detailed table of contents at the end of the book (a general index and a bibliographical section are to be appended to Vol. II), is appears to be as fully exhaustive of the subject as the acknowledged standard works previously published in Europe and America and should prove a most useful textbook in Hungarian technical high schools of university rank.

There is an abundance of excellent diagrams, graphs and tables; the half-tones, however, are not up to the same standard, as most of them—if not all—have too obviously been reproduced from photographic illustrations in other publications. Besides, the plates on which they are shown, instead of accompanying the text to which they refer, are, with one single exception, inserted by groups of 15 or 16 at the end of each main section of the work, and their numbering is different from that of the line figures. This layout is all the less satisfactory as in too many instances—Soviet installations being a conspicuous exception—the sources from which the illustrations have been taken are not quoted. On the other hand, the five large-size diagrams of the appendix leave nothing to be desired, and print and paper are exceptionally good for a textbook.

Vol. 2, to be published at a later date, is to deal with high- and medium-head plants, as well as with the economics of water power.

Carrier Current on Power Lines. By André Chevallier. The BEAMA Journal, 36, Kingsway, London, W.C.2. 1953. 24 pp. 43 ff. Price 2s. 6d. net.

This is the substance of four lectures delivered at King's College, University of London, and subsequently published in the *BEAMA Journal*. The text forms a concise but admirable summary of the principles of carrier-current communication, and coming from the Chief Engineer of Electricité de France it is intimately related to practice on the French hydro-electric network. After a general introduction the author compares the three main methods of coupling—interphase, parallel three-phase and earth, and phase-earth—with particular reference to attenuation. The functions and characteristics of the various components are then examined. Brief sections then follow on telephony, discriminative feeder protection, telemetering, telesynchronising, and fault location.

Hydraulics of Closed-Circuit Spillways: Part I, Theory and its Application. By Fred W. Blaisdell, Project Supervisor, United States Department of Agriculture, Soil Conservation Service. Technical Paper No. 12, Series B. St. Anthony Falls Hydraulic Laboratory, University of Minnesota. Price 50 cents.

This paper discusses the control of the flow through closed-conduit spillways by weirs, the barrel exit, tailwater, pipe, orifice, and short tube, since each of these controls may govern, at some time or other, the rate of flow through the spillway. The effect of these various controls on the performance of the spillway is explained. A means of developing a composite head-discharge curve is given. Pressures within the closed-conduit spillway must sometimes be determined, so the methods for this determination are presented. A selected bibliography useful to the understanding and for the design of closed-conduit spillways is included.

Fig. 1. General view of Itutinga camp and plant site, November 1952

The Itutinga Project

Work is now in hand on the construction of a 36 MW scheme at the Itutinga Falls on the Rio Grande in the State of Minas Gerais, Brazil

THE State of Minas Gerais, Brazil, is engaged on a State-wide electrification programme, which involves the construction of several hydro-electric plants and a large network of transmission and distribution lines.

One of these plants is the Itutinga 36,000 kW hydro-electric development, situated in the southern part of the State, at 230 km. north-west of Rio de Janeiro, on the upper reaches of the Rio Grande, one of the main Brazilian rivers, which drains southwards toward the river Plate.

The main purpose of this plant is to deliver bulk power to local public utilities for distribution in the urban centres of the southern part of the State, to supply mining and metallurgical companies, and to enable the electrification of the Rêde Mineira de Viação, a government-owned railroad, to be extended. After interconnection with other projects it may also play an important role in the supply of power, by displacement, to more remote areas.

The first idea of developing the Itutinga Falls was conceived in 1921 for the express purpose of electrifying the Rêde Mineira de Viação railroad, but definite engineering studies were only started in 1949 when the State of Minas Gerais contracted with Servix Engenharia Ltda., an engineering firm from Rio, for the investigation of the site and the preparation of a preliminary layout for estimating purposes.

In November 1951, the Cia. de Eletricidade do Alto Rio Grande—CEARG—a company having part government and part private capital—was organised for the purpose of constructing and operating a power system located in the south of the State and having in Itutinga its main source of power.

The existing studies were then reviewed by CEARG and improved to be more in accordance with the market possibilities of the region and with the geological and hydrographic information of the site gathered in more recent investigations. Final engineering was assigned to the International Engineering Company of San Francisco, California, U.S.A.

General Features of Site

The Rio Grande river originates in the Mantiqueira mountains at an altitude of 1,900 m., flows for about 200 km. north, and reaches the Itutinga waterfall at an altitude of about 810 m. with a hydrographic basin of 6,210 sq. km. area. The catchment area of the Rio Grande upstream from Itutinga has the shape of a pear, with several tributaries equally dispersed. It is mostly flat and sparsely timbered.

In the project area the river flows through a strait between two massifs of gneiss and forms a semi-horseshoe towards the left, falling by 12 m. over a distance of 500 m. Immediately above the falls the river widens to 1½ km. and then narrows down before

Fig. 2. Preliminary diversion works at Itutinga, November 1952

reaching the second massif, forming a small storage basin in between.

By damming the river at the level of the Itutinga straits and by diverting the waters to the left bank there can be formed a relatively compact hydraulic installation with a head of 30 m. for a supply length

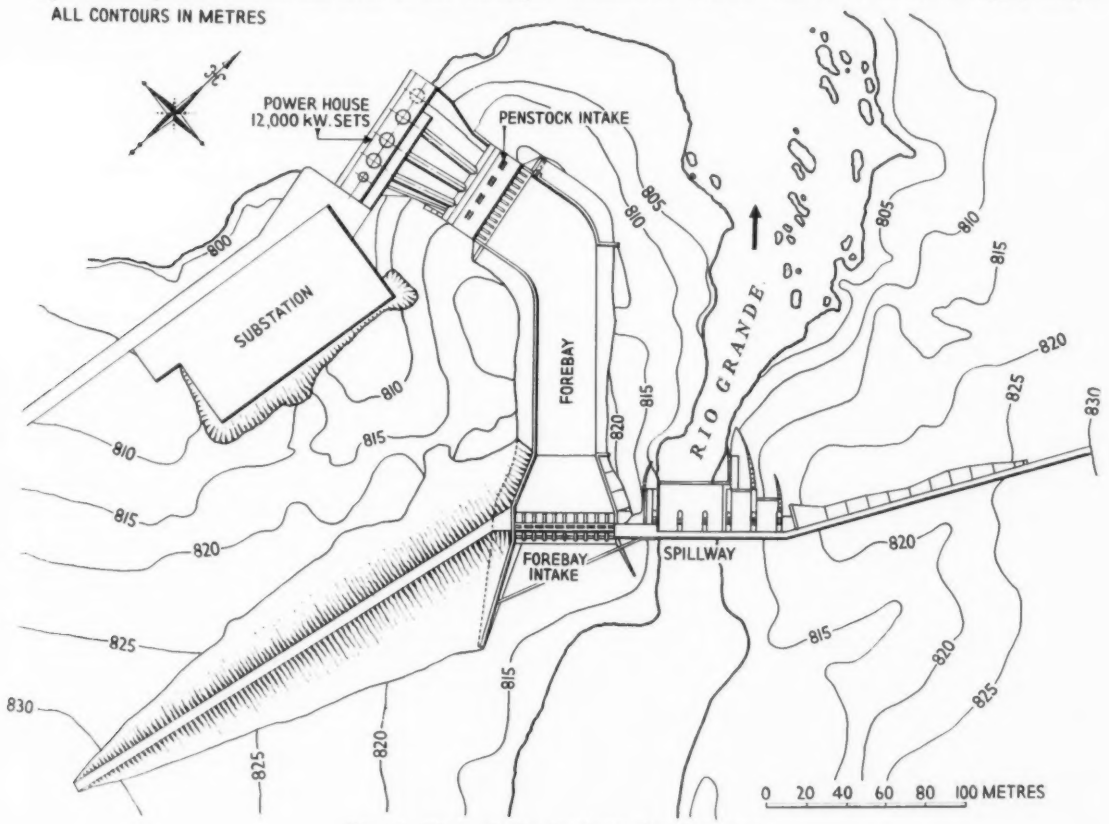


Fig. 3. Plan of the Itutinga development

varying between 200 and 250 m.

The local geological formation is very advantageous and is suitable for the construction of almost all the installation on solid rock of which most is bare.

Hydro-Electric Installation

The installation consists of a dam partly of earthwork and partly of masonry, in two distinct sections, one on the right bank and the other on the left bank; of a fore-

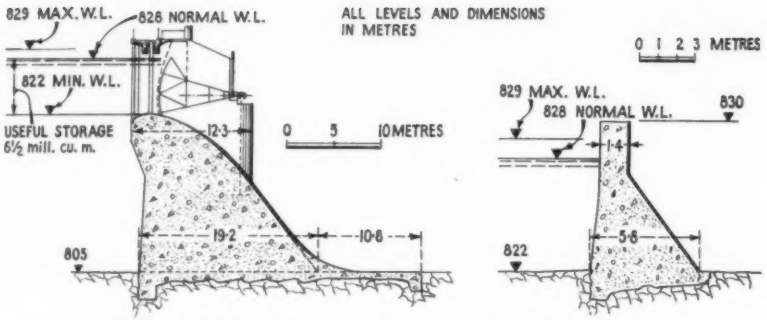


Fig. 4. Section through concrete dam and spillway

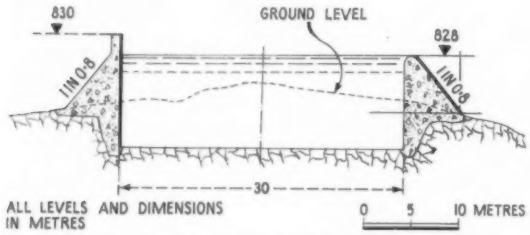


Fig. 5. Section through forebay channel

The crest of the dam is 18 m. above the normal level, thus creating a reservoir with a gross volume of 11,000,000 cu. m., and a net volume of 6,500,000 cu. m. (400,000 kWh for 6 m. drawdown). This volume is not sufficient for seasonal regulation, but can be efficiently used for weekly or daily regulation.

The forebay canal has a length of 168·2 m. and a width of 30 m. and is sufficient to supply four 12,000 kW units at minimum reservoir level. The intake to the forebay will be provided with trash racks and a boom for diversion of floating logs and water plants carried by floods.

The penstock intake will have space for four main

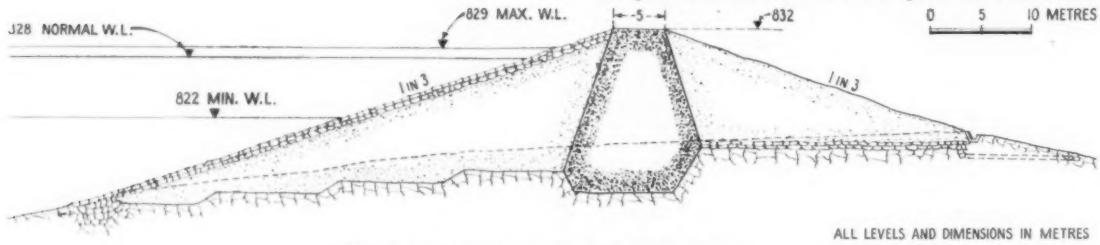


Fig. 6. Section through earth embankment

bay excavated in the rock along the left bank, the water intake of which is located between the two dam sections; of an intake structure from which issue the penstocks, one for each unit; of a power house designed at the moment for four vertical 12,000 kW units; and of a short tailrace canal.

The right wing of the dam is of the mass concrete gravity type, with a total length of 246·5 m., and a maximum height of 23 m. from top of crest gates to foundations. The spillway has a gross length of 64·5 m., and is provided with five sector-type crest gates, each 10·5 m. wide by 6 m. high.

The earth dam will be of the conventional type with slopes of approximately 3 : 1. It will have a maximum height of about 14 m. and a length of 253 m.

The spillway is designed for a discharge of 1,560 cu. m. per sec. under normal conditions (water level 828 m.) with the gates fully opened; when the level in the reservoir is one metre above the normal full water level (829 m.) the discharge will be 2,230 cu. m. per sec. including the extra discharge on the right-bank abutment dam and the spillway of the forebay. The maximum filling rate observed during 22 years' recording of the Rio Grande at Itutinga was 1,000 cu. m. per sec. in 1929.

penstocks and one auxiliary penstock, and will be equipped with four steel fixed-wheel type intake gates measuring 5·79 m. height by 3·96 m. wide and designed for a maximum head of 16·3 m. The gates

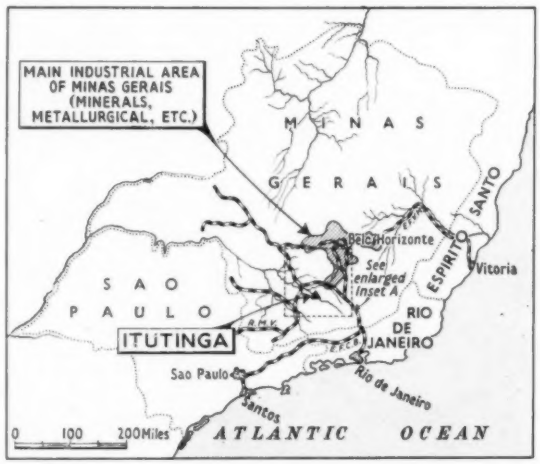


Fig. 7. Key map of Brazil showing location of Itutinga

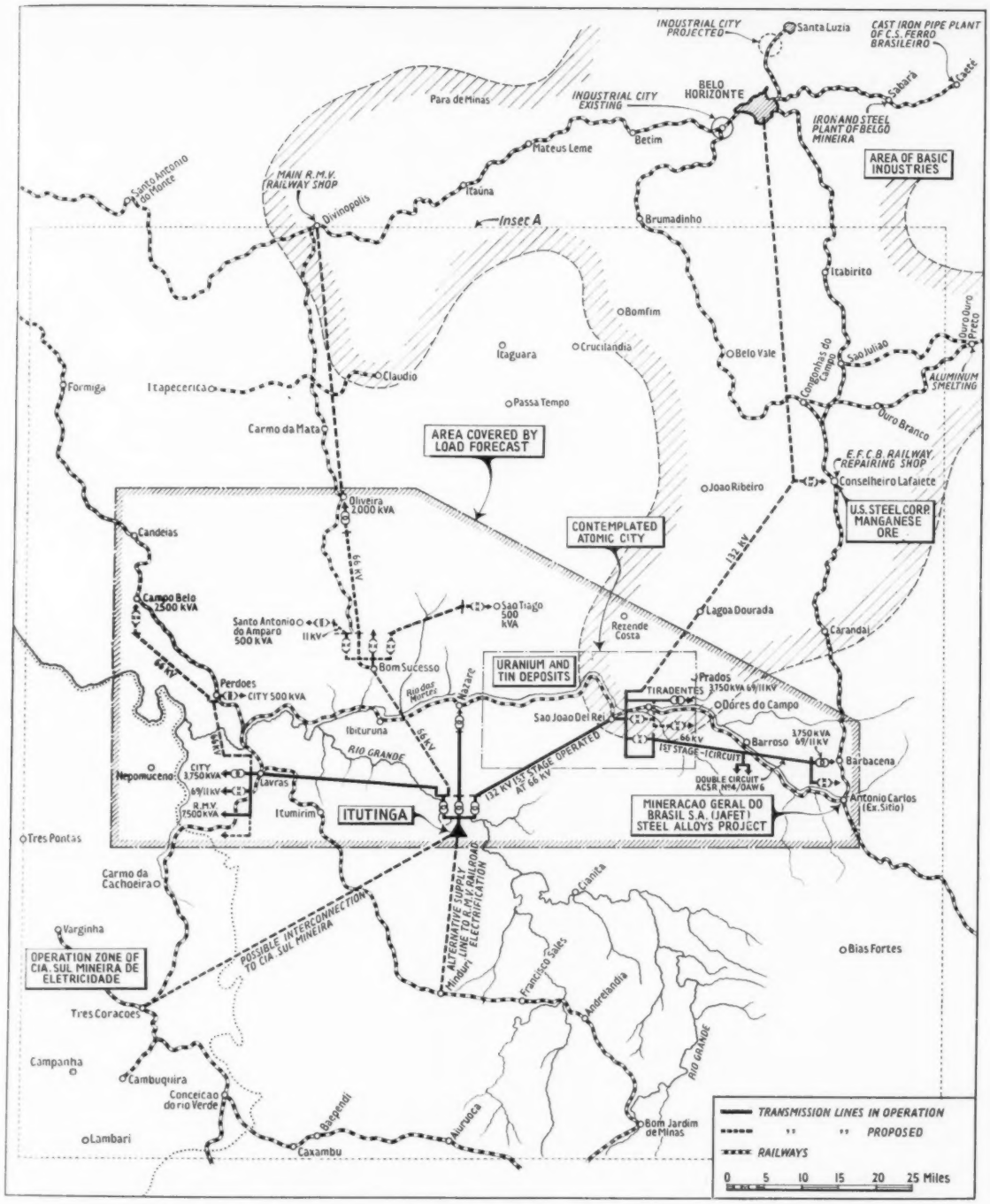


Fig. 8. Map of inset in Fig. 7 showing the area to be served by Itutinga

will be operated by 15 ton monorail hoists. The main penstocks will be of steel, each 4·20 m. diameter and about 50 m. length.

The power house will be of the outdor type with a gantry crane for the dismantling of the units and the operation of the tailrace stoplogs. At first only two units will be installed but the foundations for the third and the excavations for the fourth will be performed at the same time.

The gantry crane, 14·58 m. high with an 11 m. span, will have a main hoist capacity of 95 tons and 18 tons capacity on the auxiliary hoist for the draught tube gates.

The generating units will be of the vertical type,

each consisting of a Kaplan turbine of 17,000 h.p. at 29·5 m. head, and 225 r.p.m., provided with a Woodward governor and driving a three-phase generator, 13,500 kVA, 6,900 V, 60 cycle, 0·9 power factor, with weatherproof outdoor housing. The generator will include main and pilot exciter and will have a WR^2 of 3,280,000 lb. ft^2.

The turbines will have steel-plate riveted cases and annealed steel blades with stainless-steel reinforcement welded to the critical areas. The governors will be of the actuator type and designed to make a complete stroke in 3·5 sec. with 31 per cent. speed rise (load off) and 40 per cent. pressure rise.

There will also be a horizontal auxiliary unit consisting of a 1,075 h.p., 27 m., 450 r.p.m. Francis turbine coupled to a three-phase 920 kVA, 480 V, 60 cycle, 0·8 power factor generator.

Each generator unit will be connected direct to a step-up transformer bank of three single-phase transformers of 4,000 kVA, 66/69 kV each, with provision for a future secondary voltage of 138 kV. The transformers will operate initially at 69 kV; and will be converted to 138 kV when the power to be transmitted by the Itutinga—São João del Rei line demands it.

Turbines and valves are being furnished by S. Morgan Smith Co., of York, Penn., U.S.A., and all electrical equipment of the power plant and step-up substation by Westinghouse Electric International Company.

The plant will be built in stages, the initial installation to consist of all hydraulic works and two 12,000 kW generating units. The first unit is scheduled to be on the line by the end of 1954 and the second one by the middle of 1955.

Transmission System

Following the standardisation trends in Brazil among other large utilities the Itutinga transmission system voltage will be 138 kV for transmission, 69 kV for subtransmission and 13·8 kV for distribution. Initially, while Itutinga operates as an isolated plant supplying only the surrounding area, all outgoing lines from the power station will be operated at 69 kV with step-down 69/13·8 kV substations at points of delivery.

Later, as load conditions and transmission distances warrant, high-tension voltage at Itutinga will be stepped up to 138 kV. The lines subject to future voltage changeover will be built right from the beginning for 138 kV.

Approximately 400 km. of transmission lines of which 200 km. at 138 kV, 200 km. at 69 kV, to be built gradually, are contemplated in connection with this development. This network will have considerably more transmission capacity than the plant under construction, and will be able to distribute the power of other projects under consideration in the same area. All conductors will be of aluminium ACSR type. The structures will be either of wood or steel according to the specific condition of each line.

Plant Capacity and Power Available

Although the original plans for the Itutinga project called for only three 12,000 kW units totalling 36,000 kW of installed capacity, the forebay and intake were designed with sufficient capacity for a fourth unit, foreseeing either future secondary storage or operation of the Itutinga plant as a peak-load station with very low load factor after interconnection with other power resources in the State of Minas Gerais. Streamflow records of the Rio Grande covering a period of nearly 20 years show that during 95 per cent. of the time and with weekly pondage the flow in the river is good for a peak load of 31,100 kW at 50 per cent. weekly load factor. On the basis of dry season flow the average annual output of Itutinga will be about 180,000,000 kWh.

Power Market

The initial market for the power of Itutinga will be the towns of Lavras, São João del Rei and Barbacena, and a certain number of industrial enterprises such as a cement mill, a steel alloys plant and a tin mine located in the same area. Later a railroad will be electrified and various other communities and industries connected to the system.

The construction of this development will permit the closing down of various small and inefficient hydro and diesel plants which at the present time serve the Itutinga region very inadequately.

Financing of Project

The Itutinga power station and related transmission system is being built by the Companhia de Eletricidade do Alto Rio Grande—CEARG—a subsidiary of Centrais Elétricas de Minas Gerais SA—CEMIG.

The project is being financed partly with company capital and partly by a U.S. $7,300,000 International Bank (IBRD) loan. The capitalisation of CEARG, which is a company sponsored by both Government and private capital, is guaranteed by the State, which, through CEMIG, devotes to this purpose a 4/14 levy of the economic reconstruction tax, which feeds the electrification fund of the State. The initial capital of CEARG was subscribed to the extent of 11·4 per cent. by about 1,200 private parties in the area of Itutinga.

B.E.A.M.A. Dinner

In the course of an address given at the annual dinner of the British Electrical and Allied Manufacturers' Association, Sir Harry Railing, the president, stated that we now shared with the United States of America the position as a leading electrical export country, our direct export of electrical equipment amounting to £220 million per annum. This sum represented 7 per cent. of the value of the total exports of the country, and had been achieved by voluntary co-operative effort among the manufacturing firms. The electrical industry, he added, now employed some 600,000 workers and was supported by its own research, development and production organisations in such a way as to leave individual concerns perfectly free to join or not in any specific activity, and to adopt their own methods in tackling problems. This freedom had led to a success which was not only illustrated by the growth of individual firms but also by their increasing number.

The Rt. Hon. Henry Willink, Vice-Chancellor of Cambridge University, also spoke, paying tribute to the wide educational activities of the Association and referring, in particular, to its farsightedness in endowing a Chair of Electrical Engineering at Cambridge University, now held by Professor E. B. Moullin, Sc.D.

Self-Priming Pumps. A Pamphlet from Gilbert Gilkes & Gordon Limited, Kendal, describes this firm's well-known heavy-duty self-priming pumps as applied to marine service.

Minnesota International Hydraulics Convention

This Convention, which combined the fifth plenary meeting of the International Association for Hydraulic Research and the second separate meeting of the Hydraulics Division of the American Society of Civil Engineers, was held at the University of Minnesota in September. We summarise some of the papers having relevance to hydro-electric practice.

PART THREE

AN interesting paper on air entrainment in vertical shafts was contributed by G. Marquenet, of the National Hydraulic Laboratory of France, entitled "Air Entrainment by Flow in a Vertical Pipe and Application to Secondary Supply Shafts."

In a vertical or inclined supply shaft connected to a pressure tunnel there is a difference in flow conditions above and below the piezometric line. Above this line the shaft is not under pressure and flow takes place freely at high velocity with a tendency to entrain air. At very low discharges the water flows down the walls of the shaft, and as the discharge increases the flow takes the form of a sleeve of water surrounding an aerated core in which the water flow takes the form of rain. As the discharge is further increased a point is reached—known as the point of engorgement —at which the entry becomes drowned, and thereafter the shaft operates under drowned conditions with no air entrainment.

Fig. 10 gives the general type of discharge/head curve obtained, and shows that under free flow an increase of head results in a relatively large increase in discharge, but beyond the point of engorgement an increase in head gives rise to only a negligible increase in discharge.

Curves of this type were obtained in experiments which were carried out with plexiglass tubes 150 mm. in diameter and 3·56, 5·76 and 13·50 m. long. An inlet chamber was so arranged that inflow could take place either at atmospheric or at reduced pressure, and the discharge from the bottom of the tube was free.

This characteristic points to the existence of a maximum discharge for any particular discharge, and the following formula is deduced:—

$$Q = 0{\cdot}9 \text{ to } 0{\cdot}95\ m\frac{\pi d^2}{4}\sqrt{2\,g\,(h + \frac{p_a}{\omega})}$$

where m is a constant.

Below the piezometric line any air entrained in the free-flow section tends to become entrapped. At very low discharges the velocity of water flow is less than the velocity of air release, and de-aeration will proceed naturally, but when the water velocity exceeds that of air release some or all of the entrained air will be carried into the pressure tunnel.

Experiments with the apparatus described showed that the length of the emulsion zone was not affected by the position of the piezometric line provided that the height of the free-flow section was more than 2 m. There was, however, a critical velocity of flow—of the order of 13 cm. per sec. for the 150 mm. tube —beyond which the emulsion zone filled the tube and travelled downstream at a speed which increased with the discharge.

The author then proposes a "maximum depression" syphon, shown diagrammatically in Fig. 11, which will enable a secondary shaft to be supplied without air entrainment at all flows. A supply chamber *a* is so designed that the water feeding into it is de-aerated either naturally or by some specific device, and the upstream leg *b* of the syphon is made longer than the

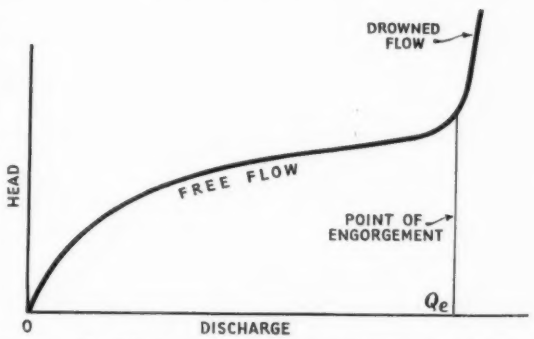


Fig. 10. Discharge / head curve for vertical shaft

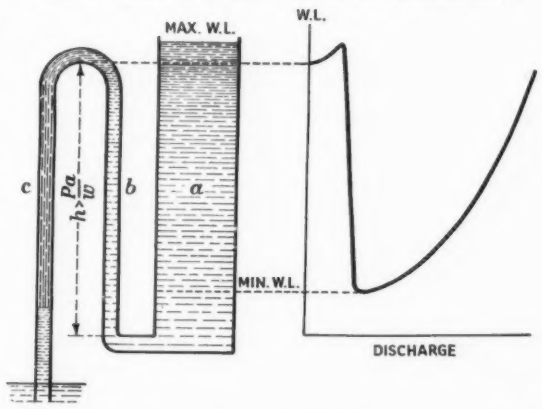


Fig. 11. Maximum-depression syphon proposed by Marquenet

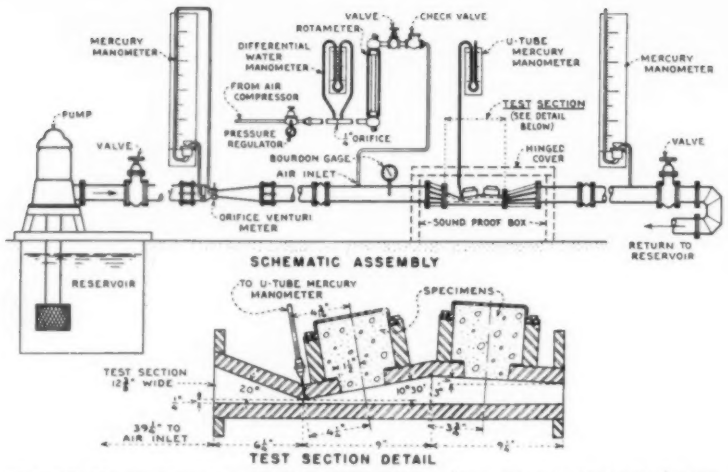


Fig. 12. Venturi-type cavitation apparatus using concrete test specimens

barometric head so that the syphon can never be broken. At very low flows a column of vapour and dissolved air (shown by vertical shading) stands in the downstream leg *c* of the syphon, but when the discharge velocity exceeds that of natural de-aeration the syphon fills and the water level in chamber *a* falls to a minimum as shown in the diagram, thereafter rising again as the discharge increases.

An American research on the same problem was outlined in a paper "Air Entrained by Water Flowing Down Vertical Shafts" by Louis M. Laushey and F. T. Mavis, of the Carnegie Institute of Technology. Measurements were made of the quantities of air entrained by water flowing down vertical shafts 30 ft. in length. The shafts were Lucite, 2·8 in. and 5·6 in. in diameter. The volumes of air entrained depended on the following variables: the type of entrance to the top of the shaft; the distance from the inlet to the hydraulic grade line in the shaft; the rate of flow of water; the diameter of the shaft; and the amount of suction in the top of the shaft. For spiral flow in these two shafts, the ratio of air to water depended primarily on the distance of free fall to the hydraulic grade line (proportional to the square of the velocity). This variable was also of most importance when the flow entered the top of the shafts radially, although the amount of suction and the shaft diameter affected the air-water ratio.

A study of water falling into a basin and a comparison of its behaviour with that of a submerged jet was contributed by Masashi Hom-ma, Tokyo University, Japan, in a paper entitled "An Experimental Study on Water Fall."

An important subject was ventilated in a paper "The Effect of Entrained Air on Cavitation Pitting" by Alvin J. Peterka of the U.S. Bureau of Reclamation. The paper commences with a general summary of the cavitation problem and then proceeds to describe some laboratory tests on the effects of entrained air. The first series of tests was carried out with a magneto-striction oscillator which was designed to vibrate a brass disc in water at 7,800 cycles per second over a travel of 0·0045 in. Because of the inertia of the water, cavities form beneath the disc on the upward stroke and are collapsed on the downward stroke. A ten-minute run resulted in cavitation pitting sufficient to reduce the surface of the disc to the texture of fine sandpaper, but a second ten-minute run with a similar disc in which an air stream was directed against the bottom of the disc showed greatly reduced pitting.

Tests on concrete specimens were then conducted in the venturi-type cavitation apparatus depicted in Fig. 12. A rapidly expanding downstream section was used to produce cavity-collapsing pressures, and space provided to insert two concrete test blocks. A compressed-air line was used to inject air into the flow as desired. Cavitation was sufficiently severe to cause appreciable damage in one hour, but all specimens were tested for two hours so that the weight loss of the specimen could be more accurately measured. Tests with various percentages of entrained air gave the results shown in Fig. 13. An increase in air entrainment reduced the loss due to cavitation pitting, and for 7·4 per cent. of entrained air the loss was not measurable. The region between 1·5 and 2·5 per cent. appeared to be very critical, and indicated a transition zone the significance of which was not obvious.

The other curve in Fig. 13 plots air entrainment against cavitation number. Cavitation numbers were computed using the pressures obtained for the various air contents, the velocity head based on the measured discharge, and the flow area at the piezometer location, using the equation

$$K = \frac{h_o - h_v}{V^2 / 2g}$$

where h_o is the head measured at the piezometer,

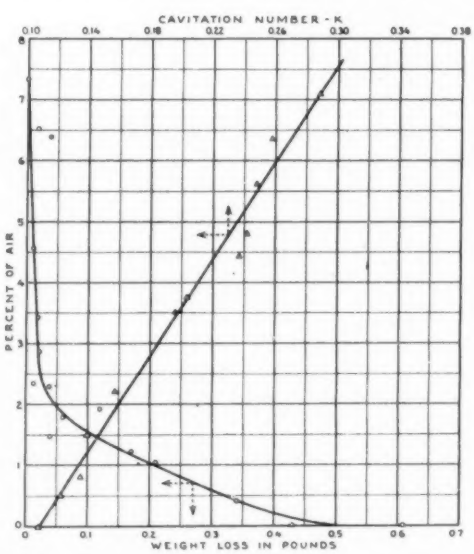


Fig. 13. Test results from venturi-type cavitation apparatus

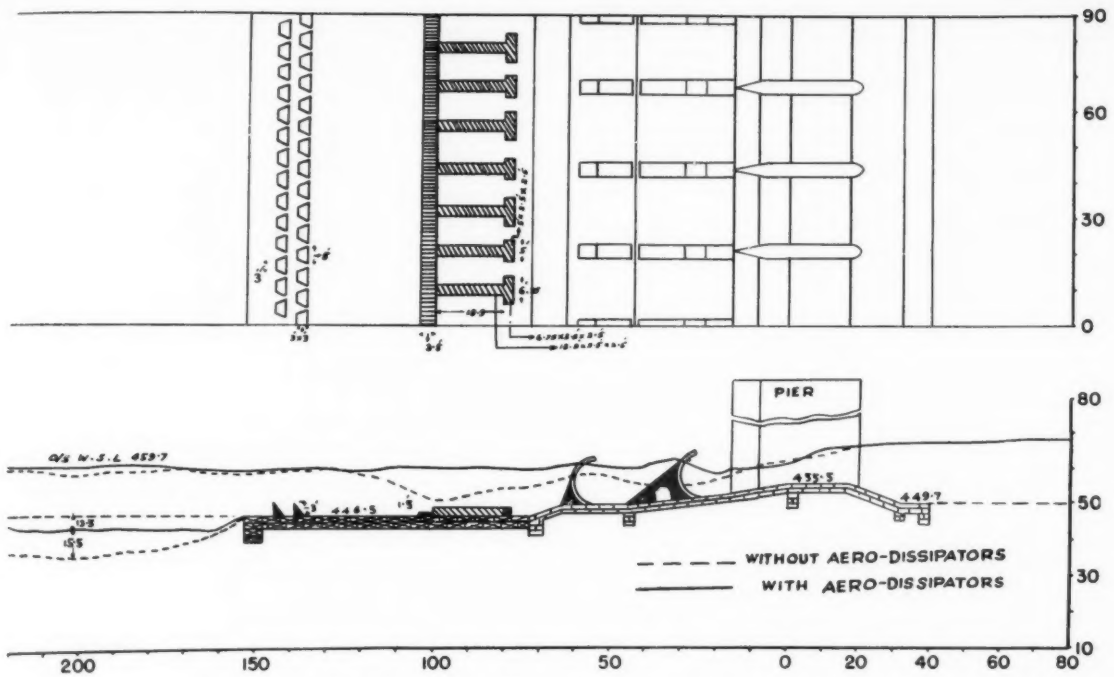


Fig. 14. Model of Sidhnai weir showing Aerodissipators and Aerobaffles

h_v is the difference between atmospheric pressure and the vapour pressure of water, and $V^2/2g$ is the velocity head, or maximum possible pressure rise at the piezometer.

The cavitation numbers thus obtained, plotted against the percentage of entrained air, showed a straight-line variation as shown in Fig. 13. An increase in the cavitation number indicates a decrease in the tendency toward cavitation. The cavitation number varied from 0·109 with no air flowing to 0·288 for 7·1 per cent. air. Thus, the entrainment of air in the flowing water increased the cavitation number (other flow conditions were identical) by increasing the pressure in the low-pressure or cavity-producing area.

In the concluding section of the paper the effect of air entrainment on cavitation pitting on the Heart Butte and Grand Coulee spillways is discussed.

Devices which have been found to correct conditions of flow at weirs and canal falls by entraining air in the supercritical flow are described in a paper entitled "Air Entraining Devices and their Use in Correcting Flow Conditions at Weirs and Canal Falls" by Mohammed Abdul Hamid, R. F. T. Farrant, and Mushtaq Ahmad, of the Irrigation Research Institute, Pakistan. The first device — an Aerodissipator — consists of a semicircular hook-shaped obstruction (see Fig. 14) placed in the supercritical jet. It changes the direction of impinging water in an upward circular motion, and centrifugal action spreads it sideways forming envelopes enclosing air. The high-velocity jet moving under the envelopes sucks in and entrains air contained in the envelopes. This device improves condition of the flow on a weir or a fall, where, as a result of heavy downstream retrogression, the supercritical flow changes to subcritical through undular motion without dissipation of energy. Under conditions caused by retrogression an ordinary sill, a baffle wall, or staggered blocks only cause hurdling action or a subsidiary standing wave on the loose protection, which is dangerous. The Aerodissipators, by splitting and spreading the jet and by air entrainment, change the supercritical flow to subcritical without undular and wavy motion and without the formation of a secondary hydraulic jump. From experiments the best position and spacing for the Aerodissipators have been suggested.

Another device, called an Aerobaffle, used alone or in conjunction with aerodissipators, has been found to correct lateral velocity distribution for a stream emerging from a constricted section into an expansion. This device is also used in the supercritical jet where, by splitting the jet and entraining air, it corrects lateral velocity distribution below flumed hydraulic structures.

In a paper "Air Demand in Gated Outlet Works" by F. B. Campbell and B. Guyton, Waterways Experiment Station, U.S. Corps of Engineers, the functions of air vents in gated outlet works are discussed briefly. The shortcomings of earlier design concepts due to lack of physical data are mentioned. Field measurements of air demand at Corps of Engineers dams are summarised. A graph of air demand versus per cent. gate opening indicates maxima at very small gate openings and at approximately 80 per cent. gate opening.

A theoretical approach to the solution is based on the laws of turbulent flow. The motivating force of the air with the conduit flowing partly full is considered to be the drag of the rough water surface at high velocities. Both roof and side-wall drag are ignored in this approach. The theoretical discussion reaches the conclusions that the roof drag of a sluice must be taken into account and that experimental

data on the distribution of velocity in the air flow are needed.

The field measurements are compared with the laboratory tests of Kalinske and Robertson. The field measurements show a substantially larger air-water discharge ratio than do the laboratory tests for a given Froude number. A suggested design criterion for air vents based on the field measurements is presented.

Miscellaneous Papers

Experiments on water infiltration are described in a paper "Experiments Concerning the Infiltration of Water through a Rock Mass" presented by L. Escande, Ecole Nationale Superieure d'Electrotechnique et d'Hydraulique, France. These researches concern the infiltration of water through a permeable medium consisting of pounded pebbles having more or less sharp corners. The author took as a basis the following hypothesis: for sufficient Reynolds numbers, the flow must reach a high degree of turbulence. The head-loss i per length unit must vary as the square of velocity V of infiltration :

$$V^2 = Bi$$

where B is a constant coefficient called the coefficient of permeability of the turbulent medium.

A series of experiments has been carried out to verify this point.

(1) Pressure flow inside a vertical pipe (diameter, 40 cm.) through a mass 402 cm. thick. It has been observed that the head loss is more important in the lower part than in the higher, owing to the settlement of the pebbles under the weight of the mass. The curves V^2/i in function of V have first an ascending aspect and eventually become practically horizontal, as soon as V exceeds 29 cm. per sec. The aforesaid hypothesis is therefore confirmed by this result: the infiltration represents a really turbulent flow in which the head losses are proportional to the square of velocity.

(2) Flow in a pipe with a square cross section (30×30) through a mass 100 cm. thick. Owing to the settlement, the coefficient B varies noticeably.

(3) Flow of water through a dam of constant thickness, erected on a horizontal impermeable basis. This dam is erected in a canal 30 cm. wide with glass side walls. The mass has a thickness of 80 cm.

For several discharges, the value of B has been found practically constant and equal to 290.

Papers on translation waves include "Action of Side Weirs and Tilting Gates on Translation Waves in Canals" by Giulio De Marchi, Politecnico di Milano, Italy, and "Theoretical and Experimental Studies of the Propagation of the Translation Waves in Open Channels" by J. Nougaro, Ecole Nationale Superieure D'Electrotechnique et d'Hydraulique, France.

New Atlas Diesel Rock Drill

One of the most revolutionary advances of recent years in tunnelling technique has been the Swedish method of using light-weight drills supported on air legs and equipped with drill steels shod with hard-metal bits, as opposed to the heavy drifter. The Atlas Diesel organisation, one of the pioneers of this development, has now made a further advance by placing on the market a drill the performance of which is claimed to be a great improvement on that of previous designs.

The new drill, known as the 754, is claimed to have a piston speed about 50 per cent. greater than that of other light-weight drills of approximately the same size, and is built to deliver 3,050 blows per minute at a stroke of 1·77 in. Its air consumption at 85 lb. per sq. in. is 127 cu. ft. per min., but it exercises a wide tolerance as to air pressure and can operate satisfactorily in extreme locations where the pressure is seriously reduced.

In mechanical construction the keynote is simplicity. A splined piston is employed in place of a rifle bar to rotate the drill, and the drill retainer is a simple shackle which dispenses with bolts, lock washers or springs. Air or water flushing can be applied at will by means of a single lever having air, neutral and water positions. The drill is 24 in. long overall and weighs 48 lb.

The Atlas Diesel 754 high-speed drill

Comparative tests have been carried out in various types of strata and in various conditions, and it is stated that no machine of anything like the same weight has so far come within 25 per cent. of the performance established with the 754; indeed, its performance on gross drilling speeds is said to be superior to that of even heavier machines.

We were recently invited to attend a demonstration of this drill at a Kent ragstone quarry. A demonstrator had been

Steel Length	Bit Dia.	Test in Andesite			Test in Quartz		
		Air Pressure	Time Taken	Rate of Advance	Air Pressure	Time Taken	Rate of Advance
ft.	in.	lb./in.²	min./run	in./min.	lb./in.²	min./run	in./min.
2·65	1·339	94·8	1·23	25·6	90·2	1·17	26·9
5·25	1·300		1·65	19·1		1·48	21·3
7·9	1·260		2·13	14·8		1·66	19·0
10·5	1·221		2·45	12·9		1·81	17·4
Totals			7·47	16·9		6·14	20·6

deliberately chosen who was not a trained driller, but on our own timing he drove a 5 ft. 3 in. steel furnished with a 1·535 in. bit at a rate of 15 in. per min., dry drilling. Figures quoted to us on colliery headings include a case where a net penetration of 21 in. per min. was achieved in laminated blue shale with a $1^{17}/_{32}$ in. bit although the air pressure was down to 68 lb. per sq. in. The average gross speed over the whole round of 36 holes was 19 in. per min. At another colliery in hard post operating at an air pressure of 84 lb. per sq. in. 75 ft. of drilling was done in a gross time of 53 min., giving a gross speed of 17 in. per min. in a roadway 14 ft. wide by 10 ft. high, all holes being drilled off the floor. This necessitated the use of an extension leg for drilling the top holes. Finally, the figures in the accompanying table have been compiled from recent tests at Broulan Reef Gold Mines, Canada. The figures in each test represent the average of ten holes.

The 754 drill has been submitted to extensive tests in various parts of the world and is now available on a production basis.

New Deepwell Pumping Principle

A new principle in deepwell pumping has been introduced by Gilbert Gilkes & Gordon Limited, Kendal, which makes use of the elasticity of water. As will be seen from the accompanying diagram, the pump has a mechanically operated delivery valve which is closed when the piston is moving down and opens on the upstroke. A footvalve is fitted at the bottom of the lift pipe. On the down stroke the piston compresses the water in the lift pipe, and as the piston begins to move up the delivery valve opens, releasing the compressed water. Thus the whole column of water in the lift pipe jumps up, allowing water to flow from the well through the footvalve. A similar amount of water is at the same time delivered from the pump into the rising main.

The advantage of this construction is that, except for the footvalve, there are no moving parts in the bore. The pump is accessibly mounted at the top of the well and is driven by a standard electric motor or other source of power. The footvalve is easily withdrawn without the use of heavy lifting gear and without disturbing pipework.

The pump has a range of 60 to 600 g.p.h., a maximum lift of 200 ft. and a maximum delivery head of 100 ft. Its speed, which depends on the duty, ranges from 240 to 600 r.p.m., and it requires 2 h.p.

Arrangement of "Gilgo" deepwell pump

New Pegson Rammer

Pegson Limited, Coalville, Leicestershire, have recently introduced a new streamlined power rammer which it is claimed will give increased compaction and maximum dry density with simpler operation and lower running costs. The rammer has been completely redesigned to represent a distinct improvement on current models. The height of jump, which is maintained over much longer periods, has been increased and the larger-diameter foot, as recommended by a report of Road Research Laboratories, gives 23 per cent. greater coverage. Power has been increased by 18 per cent., and the number of blows has been maintained between 60 and 80 per minute, resulting in fewer passes for effective consolidation. Oil consumption has been reduced by two-thirds, and the lubrication of cylinder walls and all moving parts has been

Pegson rammer in action

considerably improved. The petrol/oil fuel system has been completely redesigned and a needle-type carburettor incorporated.

A new streamlined dome which protects the rammer magneto and other vital operating parts against the weather and damage, dispenses with the necessity for a waterproof cover. The overall height of the rammer has been decreased by 6 in. to reduce operator fatigue. An operating ring, which also acts as a guard, supersedes the earlier operating handles. All of these improvements have been achieved without any increase in petrol consumption.

Abstracts from the World Technical Press

Raquette River Development

The Raquette, one of the streams that rise in the Adirondack Mountains, N.Y., falls into the St. Lawrence almost exactly at the point where the great river ceases to form the border between Canada and U.S.A. and enters Canadian territory. Niagara Mohawk Power Corporation, which has waged a long and spectacular fight for the right to harness new power at Niagara Falls, operates already nine of the thirteen existing hydro-power plants on the Raquette River, has extended its development upstream and is now in the midst of a seven-year £9 million construction programme that will put five new generating stations on the line by 1957, thus adding 100,000 kW to system capacity. The scheduled programme now includes six dams, one for each generating station, and one impounding a primary storage reservoir, with the following main characteristics:—

Dams	Height	Length	Gross head	Generator output	Completion date
	ft.	ft.	ft.	kVa	
South Colton -	45	600	85	21,500	April 1954
Five Falls - -	50	500	104	25,000	Jan. 1955
Rainbow Falls	78	600	102	25,000	Nov. 1955
Blake Falls -	50	600	69	16,000	Aug. 1956
Stark - - -	40	235	105	25,000	June 1957
Carry Falls -	70	830	—	—	Nov. 1952

The key unit, Carry Falls dam, farthest up the Raquette, begun in 1951, was finally completed last year; it is primarily intended for river-flow regulation, though there is provision for a small power unit. Almost all of the programme's power, however, will be generated at the five dams downstream from Carry Falls dam. All dams will be concrete structures with ogee overflow cross sections, and each of them will back a reservoir to the tailwater level of the power station next upstream. South Colton dam and Five Falls dam are in course of construction; work on Rainbow Falls dam, the third of the power plants, is to start on January 1, 1954, and an access road is now being built to the site. The two remaining structures are to be placed under construction so as to reach completion in August 1956 and June 1957 respectively. (*Engineering News-Record*, Vol. 151, No. 12, Sept. 17, 1953, p. 30, 3 pp., 8 ff.)

Accidents in Swiss High-voltage Plants

A comprehensive set of statistics is published by the Swiss Inspectorate of HV plants for the year 1952. Accidents due to the electric installations of the State Railways are not included. Compared with the year 1951, the total number of accidents has increased from 243 to 280 but there is a slight decrease in fatal casualties—23 against 24, i.e. about 2 per cent. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 44, No. 22, 31.10.1953, p. 945, 8 pp., 6 tables.)

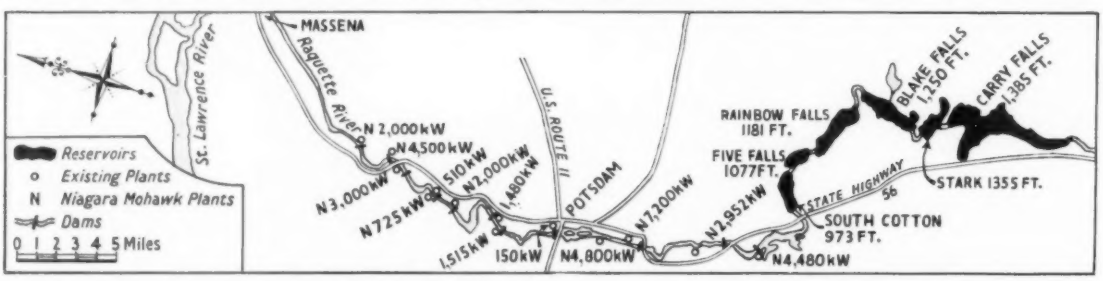
The Bort Development

The Bort dam and the Rhue diversion, which are generally considered as the outstanding feature of the Dordogne development, are briefly described. The main characteristics of the arch gravity dam are:—

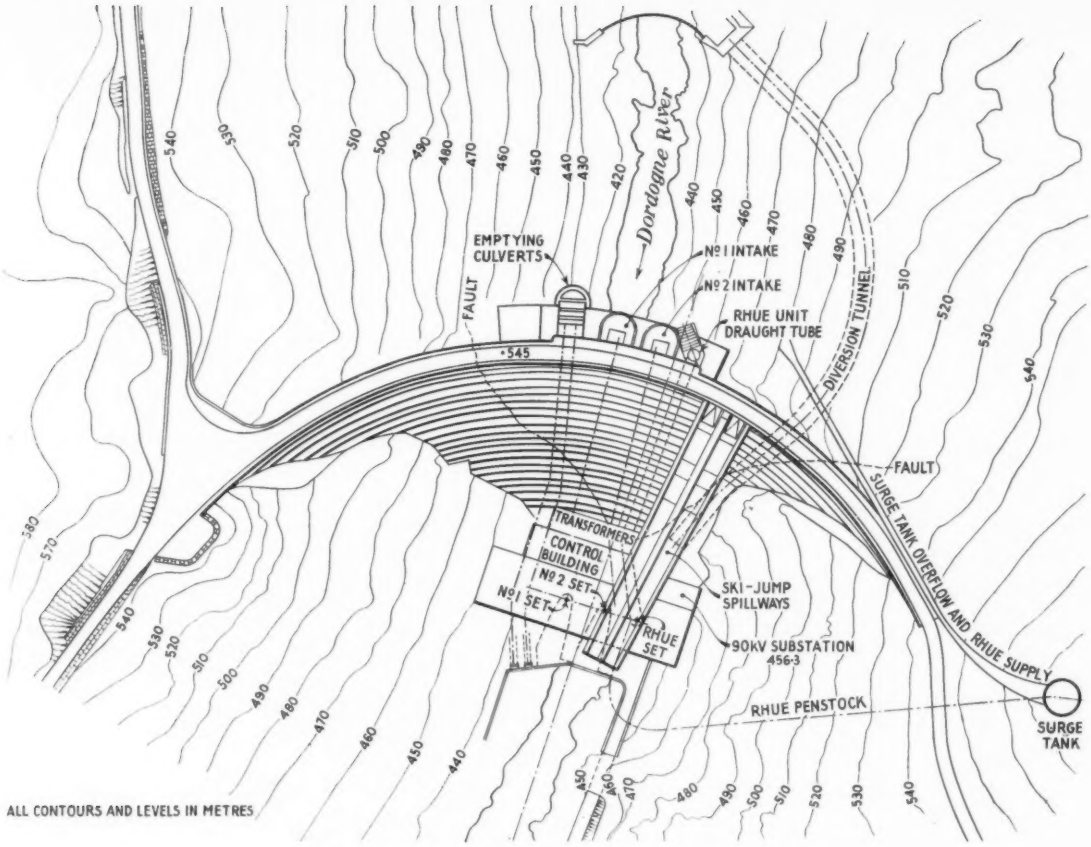
Total height	120 m.
Length of crest	390 m.
Radius of upstream vertical face	190 m.
Downstream batter varying up to	1 : 1
Double ski-jump spillway	1,200 cu. m. per sec.
Two 3 m. dia. outlet culverts	400 cu. m. per sec.
Excavation work	180,000 cu. m.
Volume of concrete placed	700,000 cu. m.

The setting up of the foundations of the works encountered enormous difficulties which could only be overcome through large-scale strengthening operations. On the other hand, the mixing, handling and placing of concrete gave Electricité de France and their contractors the opportunity to work out and apply new methods, such as the use of finely ground blast-furnace slag as an additive to cement, prefabricating on site of concrete facing blocks, cooling of concrete by cold-water circulation, etc.

The Rhue diversion works consist fundamentally of the intake structure at the Vaussaire dam, and a 12 km. long supply tunnel comprising two syphon stretches, and discharging 60 cu. m. per sec. This diversion will feed the Bort reservoir with 550 million



Map of the Raquette River showing existing and proposed developments



Plan of the Bort dam, power station and hydraulic works

cu. m. of water in an average year, in addition to the 900 million cu. m. coming from the Dordogne river. This emphasises the importance of the diversion with regard to filling the reservoir every spring.

The power house, backed by the control room, stands at the foot of the dam; its yearly production is estimated at 350 million kWh, of which 300 million is produced by the two main Dordogne units, and 50 million by the Rhue unit. The latter consists of a Kaplan turbine, a record holder as to head (32,000 h.p. at 70 m., limited to 21,000 h.p. at 80 m., and capable of operating at 15 m.) and a 25,000 kVA alternator. This unit operates between the levels of the Vaussaire and Bort reservoirs and discharges through the dam into the Bort reservoir.

Each of the two Dordogne units is fed by a 5·2 m. conduit, and consists of a vertical shaft Francis turbine with an output of 136,000 h.p. and a speed of 187·5 r.p.m. at a head of 115 m. These two 100,000 kVA units are among the three or four largest sets now in operation in any country. The outdoor transformer station is sited between the dam and the control room, and feeds one 90 and two 220 kV lines.

The artificial lake created by the Bort dam is today the largest of all French reservoirs (470 million cu. m., of which 400 million can be utilised for power generation); it fully ensures the working of the downstream chain of plants at periods when the French grid is confronted by the maximum demand of energy (*La Houille Blanche*, Vol. 8, No. 2, May 1953, Supplément graphique following p. 306, 12 pp., 17 ff.)

NOTE.—The plan accompanying this article is taken from *La Houille Blanche* publication "Bort," reviewed in our issue of July 1953, p. 267.

Fly-ash Concrete Dam

For every three bags of cement there are 92 lb. of fly ash in Baltimore's Liberty dam, now being completed on the north branch of the Patapsco River. The use of this pozzolanic material was influenced by the economy achieved with it at Hungry Horse dam, Montana, where about £536,000 was reported saved, compared with the expenditure on pure cement concrete. All the usually mentioned advantages of the pozzolanic replacement for cement are claimed for the Liberty dam concrete: low heat of hydration, increased workability, reduced segregation and bleeding, and increased later strength. The specification set up by the city's Bureau of Water Supply for the fly ash used was as follows:—

Silicon dioxide	min. 40%
Aluminium oxide	min. 15%
Carbon	max. 10%
Moisture content	max. 3%
Fineness (sq. cm. per gm.)	min. 2,500

Type 2 Portland cement was specified along with the fly ash for its low heat advantage, and an additive was used for air entrainment. The mix for the face

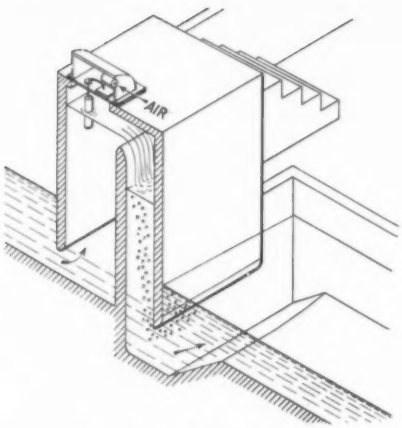


Fig. 1. Hydro-pneumatic regulator

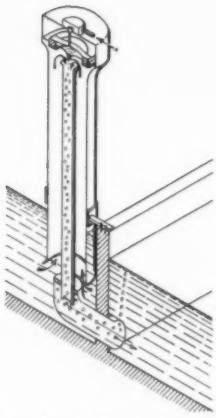


Fig. 2. Adjustable-vacuum syphon fitted with ejector

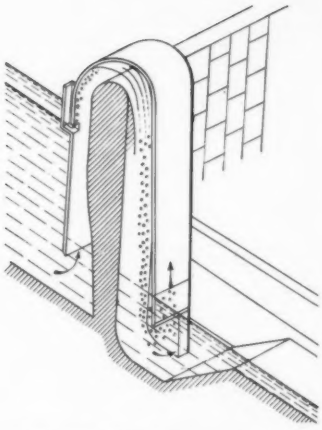


Fig. 3. Constant-upstream-level syphon

of the dam got an extra bag of cement per cu. yard of concrete.

An uncommon and highly interesting feature of this water supply project is the aluminium suspension bridge which connects the 178 ft. high tower intake with the shore, about a mile and a half upstream from the dam. This bridge has a span of 270 ft. between the gatehouse set up in the top section of the intake tower and the 34 ft. high steel tower fitted on a concrete pier at shore, and there is another 40 ft. from pier to shore anchorage. The two 1 in. pre-stressed single-span galvanised bridge cables anchor into the roof of the gatehouse and the concrete ashore with galvanised steel backstays. The 4 ft. footway is a 1 in. aluminium subway grating suspended by $\frac{5}{16}$ in. galvanised wire-rope suspenders spaced 9 ft. on centre; it has an aluminum pipe railing each side. The floor system consists of two 12 in. aluminium channels at 10·67 lb., with cross bracing of $3 \times 2\frac{1}{2}$ in. angles. The bridge has a camber of 4 in. (*Engineering News-Record*, Vol. 151, No. 12, Sept. 17, 1953, p. 35, 2 pp., 4 ff.)

Recent Research on Syphons

A description is given of three novel designs of syphon spillways which, it is claimed, enable overflow discharges to be regulated under widely varying conditions.

No. 1, called a "hydro pneumatic regulator," is a partly primed syphon (Fig. 1) in which the degree of vacuum is controlled by the level of the overflowing water in such a way as to keep this level constant. This apparatus makes it possible to regulate a whole range of constant discharges with highly variable upstream and downstream levels. A prototype of this apparatus discharges up to 240 litres per second at the filter outlet of a water-purifying station.

No. 2 is a highly simplified ejector fitted on to the top of a syphon of the adjustable-vacuum type, such as described sub No. 1; its design (Fig. 2) is such that air is entrained in much the same way as done by an ordinary ejector, but with a far higher efficiency.

No. 3 is an improved constant-upstream-level syphon, in which the upstream-branch cross section is constricted at the same level as an air-intake port provided in the wall of the upstream branch; a box, open at the top, forms a kind of gallery around the intake port, and the level of the water in this gallery regulates the admission of air. By means of this apparatus (Fig. 3), it is claimed that the upstream water level can be maintained constant for a very wide range of discharges, decreasing as much as to 1/12 of the maximum discharge, while the types of syphon now in operation do not allow a discharge to be regulated of less than one-third of the maximum. (Y. Ponsar, *La Houille Blanche*, Proceedings of the "Société Hydrotechnique de France," Vol. 8, No. A, March-April 1953, p. 144, 8 pp., 7 ff.)

The Châtelot Franco-Swiss Scheme

The inauguration of the Châtelot dam and power station took place on October 10, 1953. The Doubs, after the Ain, the most important of all the rivers flowing from the Jura Mountains, forms the frontier between France and Switzerland on a stretch of about 48 miles from the Brenets lake to the village of Ocourt, downstream of St-Ursannes. Only 7·1 per cent. of its catchment area lies on Swiss territory. The total gross head between the two extreme points is 336 m., of which only 103 m., or 31 per cent., were utilised by five existing plants before Châtelot came into operation. Châtelot's 97 m. head increases the head utilised on the whole stretch to 60 per cent. of the total gross head. Work on the scheme started on July 1, 1950, and the first 15,000 kW generating set was put into operation on February 23, 1953. (*Bulletin de l'Association Suisse des Electriciens*, Vol. 44, No. 22, 31.10.53, pp. 962/3, 2 ff.)

CLASSIFIED ADVERTISEMENTS

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THE PROPRIETORS of British Patents No. 655370 relating to "Improved means for guiding the flow of fluid," and No. 673062 relating to "Improvements in guiding means for annular flow of fluids" are desirous of entering into negotiations with firms in this country for the purpose of exploiting the above inventions, either by sale of the patent rights or by granting of Licences to manufacture on a royalty basis.—Enquiries should be addressed to Société Financière d'Expansion Commerciale et Industrielle S.A. "SFINDEX," Sarnen (Switzerland).